Environmental Engineering

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PART II

SANITATION

1. Introduction
2. Solid Waste Collection, Disposal and Rural Sanitation
3. Systems of Sanitation
4. Quantity of Sewage and Storm Water
5. Design of Sewers
6. Sewer Appurtenance
7. Characteristics of Sewage
8. Primary Treatment of Sewage
9. Secondary Treatment of Sewage
10. Miscellaneous Treatment of Sewage
11. Natural Methods of Sewage Disposal
12. Sludge Digestion
13. Sludge Disposal
14. Sanitary Fittings
15. Preparation of Sanitary Scheme or Project
16. Sanitation and Plumbing in Buildings
17. Bio-gas Plant

1

Introduction

1.1 DEFINITION OF DIFFERENT TERMS

1. Refuse: The rejected materials which are collected in dustbins and the foul discharges which are carried by underground drains are termed as refuse. Refuse may be of two types:

(a) Dry Refuse It includes grass, leaves, paper pieces, sweepings, decayed fruits and vegetables, cloth pieces, waste cotton, rejected plasters from hospitals, etc.

(b) Wet Refuse It includes the discharge from latrines, urinals, bathrooms, kitchens and stables.

2. Garbage: The dry refuse is also termed as garbage. It includes the sweepings from markets, public places, and streets. The rejected materials from residential area such as vegetable peel, paper pieces, ash, decayed fruits and vegetables, etc. are also included in garbage.

3. Sewage: The liquid waste from a community is termed as sewage. It mainly includes the discharges from latrines, urinals and stables. The discharges from bathrooms, and the storm water (i.e. rain water) are also included in sewage. The human excreta is termed as night soil. The sewage may be of the following types:

(a) Sanitary Sewage The foul discharges from residential area are known as sanitary sewage. It includes mainly the discharge from latrines and urinals.

(b) Industrial Sewage The discharges from the industries (i.e. industrial waste) are known as industrial sewage.

(c) Combined Sewage The combination of sanitary sewage and storm water is known as combined sewage.

(d) Fresh Sewage The sewage which is produced at the moment is termed as fresh sewage.

(e) Raw Sewage The sewage which is not yet treated is termed as raw sewage.

(f) Septic Sewage The sewage which is undergoing treatment process is termed as septic sewage. After the completion of the process of decomposition, it is termed as stale sewage.

(g) Weak Sewage The sewage which is diluted with water and contains less amount of suspended matters is termed as weak sewage.

4. Dry Weather Flow (D.W.F.): The flow of sewage during the dry season of the year is termed as dry weather flow.

5. Wet Weather Flow (W.W.F): The flow of sewage during the rainy season of the year is termed as wet weather flow.

6. Storm Water: The surface run-off during the rainfall at any place is termed as storm water.

7. Sullage: The discharge from the bathrooms and kitchens is termed as sullage. It is not a foul discharge and it does not cause bad smell.

8. Sewer: The underground conduits or drains which carry the sewage are known as sewers. The sewers may be of the following types:

(a) Main Sewer The sewer which carries the whole sewage coming from the branch lines is termed as main sewer.

(b) Branch Sewer The sewer which carries the sewage from the lateral sewers and delivers the same to the main sewer is termed as branch sewer.

(c) Combined Sewer The sewer which carries the domestic sewage and storm water is termed as combined sewer.

(d) Intercepting Sewer The sewer which carries the discharges from a number of main sewers and delivers the same to the point of treatment is known as intercepting sewer.

(e) Lateral Sewer The sewer which obtains the sewage directly from the residential buildings is known as lateral sewer.

(f) Relief Sewer The sewer which carries the excess discharge from an existing sewer is termed as relief sewer.

9. Sewerage: The network of collecting and conveying sewage by water carriage system through the underground sewers is known as sewerage.

10. Manhole: The opening or hole through which a man can enter the sewer line or other closed structure for inspection and cleaning is termed as manhole.

11. Soil Pipe: The pipe which carries the discharges from the urinals, water closets, etc. is known as soil pipe.

12. Vent Pipe: The pipe which is installed for the purpose of escaping the foul gases from the septic tanks, digesting tanks, etc. is known as vent pipe.

13. Anti-siphonage Pipe: The pipe which is installed with water closet to preserve the water seal in the trap is known as anti-siphonage pipe. This pipe maintains the ventilation properly and it prevents the siphonic action in the water seal of the trap.

14. Waste Pipe: The pipe which carries the discharge from the bathrooms, kitchen sinks, etc. is termed as waste pipe.

1.2 FEATURES OF SANITARY WORKS

The features of the sanitary works are as follows:

1. Collection
2. Conveyance
3. Treatment
4. Disposal

1. Collection

The dry refuse (i.e. garbage) and liquid refuse (i.e. sewage or night soil) should be collected in a planned way to protect the town from insanitary conditions. The following steps should be taken for the collection work:

(a) Market is the main source of garbage. The refuse like decayed vegetable and fruits, ash, mud, fish scales, etc. should be collected by labours and dumped in a particular place for removal.
(b) The swept refuse from public places should be dumped in dust-bins.
(c) The refuse from the domestic houses should be thrown in road side dust-bins.
(d) The refuse from hospitals should be collected in some particular place.
(e) If a town is under conservancy system, the night soil should be removed by the sweepers from the latrines of individual houses before dawn and collected in covered bullock carts or trailors.
(f) In water carriage system, the collection of sewage does not arise as it is conveyed through the network of pipe lines.

2. Conveyance

After collection of the garbage and night soil, they should be removed to the dumping ground by suitable conveyance. Generally, the trucks or trailors are employed for the conveyance of those refuse. The night soil carts or trailors should move to the trenching ground early in the morning.

3. Treatment

In Conservancy system, the night soil is left for natural treatment by sunshine. The garbage is separated in two groups combustible and non-combustible. The combustible garbage is burnt to ashes and non-combustible garbage is laid in low-lying areas.

In water carriage system, the sewage is carried to the treatment plant by underground sewer line for necessary treatment.

4. Disposal

There are various methods of sewage disposal (Ch. 11) and sludge disposal (Ch. 13). The effluent is discharged into the river and the sludge is digested to convert it to manure.

1.3 PURPOSE OF SANITATION

The waste products like garbage, sewage, sullage, etc. are produced everyday in towns and cities. The garbage is produced in domestic area, markets, public places, streets, etc. and the liquid waste is produced from latrines, urinals, stables, bathrooms, etc. If the garbage is not collected and disposed of regularly, then it will go on accumulating in the dust-bins. This will cause insanitary conditions by producing bad small, fly nuisance, bacteria, etc. The sources of water may also be polluted which may cause water-borne diseases. Again, if the sewage and sludge are not disposed of properly, they will also cause insanitary condition.

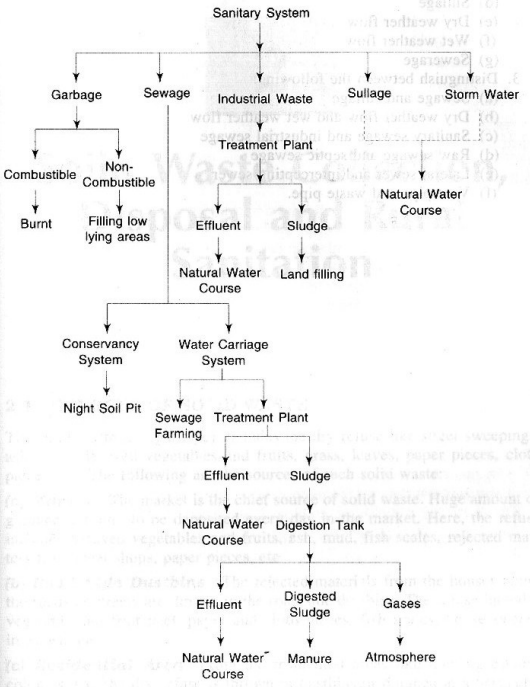
Under these circumstances, it is most necessary to establish the sanitation systems in towns or cities.

1.4 PRINCIPLES OF SANITATION

The following are the principles of sanitation:

(a) The waste matters like garbage and sewage should be removed as early as possible after its formation.
(b) The waste matters after collection should be treated within four hours and the effluent should be disposed of immediately.
(c) The floors and furnitures in a house should be cleaned regularly.
(d) The buildings should be made damp-proof.
(e) Water supply should be regular and sufficient so that the flushing of the lavatories may be done properly.

1.5 FLOW CHART OF SANITARY SYSTEM



REVIEW QUESTIONS

1. State the features of the sanitary works.
2. Define the following:
   (a) Refuse
   (b) Garbage

(c) Sewage
(d) Sullage
(e) Dry weather flow
(f) Wet weather flow
(g) Sewerage

3. Distinguish between the following:
(a) Sewage and sullage
(b) Dry weather flow and wet weather flow
(c) Sanitary sewage and industrial sewage
(d) Raw sewage and septic sewage
(e) Lateral sewer and intercepting sewer
(f) Vent pipe and waste pipe.

2

Solid Waste Collection, Disposal and Rural Sanitation

2.1 SOURCES OF SOLID WASTE

The solid waste (i.e. garbage) includes the dry refuse like street sweepings, ash, mud, decayed vegetables and fruits, grass, leaves, paper pieces, cloth pieces, etc. The following are the sources of such solid waste:

(a) Market The market is the chief source of solid waste. Huge amount of garbage is found to be deposited every day in the market. Here, the refuse includes decayed vegetables and fruits, ash, mud, fish scales, rejected matters from meat shops, paper pieces, etc.

(b) Road Side Dustbins The rejected materials from the houses along the roads or streets are thrown in the road side dustbins. The refuse includes vegetable and fruit peel, paper and cloth pieces, fish scales, house sweepings, ash, etc.

(c) Residential Area From the residential areas like housing estates, colonies, etc. the dry refuse is thrown in dustbins or dumped at a particular place alloted for the purpose.

(d) Street Sweepings The sweepings of main roads are collected in dustbins and the sweepings of the streets of colonies, housing estates, factories, plants, etc. and carried away every morning. The sweeping of main roads should be done early in the morning when there are less vehicles on the roads. The refuse mainly includes dust, grass, leaves, plants, paper pieces, etc.

(e) Cinema and Theatre Halls The sweepings from the cinema and theatre halls mainly include dust, nutshells, paper pieces, etc. The refuse are dumped in nearby dustbins.

(f) Schools and Colleges The sweepings of schools and colleges mainly include dust and paper pieces. The refuse is collected in the nearby dustbins.

(g) Hospitals The refuse of hospitals includes rotten clothes and plasters, paper pieces, waste cotton, dust, broken glass, rejected bottles of medicine, disposable syringes, injection samples, etc. These are collected and dumped in suitable place in front of the hospitals.

2.2 COLLECTION AND REMOVAL OF SOLID WASTE

The solid wastes should be collected and removed in a planned way so that unhygienic condition do not arise and the people do not feel any inconvenience due to bad odour and ugly situation. The wastes are collected and removed in the following ways:

(a) The refuse from the markets is collected by the sweeper from all corners or zones and dumped in a suitable place in front of the market. Then the materials are loaded to the truck or trailer and removed immediately to the place of dumping. The collection should be done daily in the early morning.
(b) From the road side dustbins, the refuse is collected by the vehicles and removed to the dumping ground.
(c) The refuse from the hospitals is collected by trucks and removed to the dumping areas every morning.
(d) The refuse from the schools and colleges, cinema halls, etc. is collected in small hand-driven wheel baskets and finally thrown to the receiving vehicles standing on the main road or any suitable place.

The following vehicles are employed for the removal of solid waste.

1. Rickshaw-vans: These are three-wheeled small vehicles with cover on four sides, almost like a box. The capacity of these vehicles varies from 8 to 10 cubic ft. These are suitable for narrow lanes and *kachcha* roads where heavy vehicles cannot enter. They carry the refuse up to the dumping place by the side of main roads from where heavy vehicles remove the materials to the dumping ground.

2. Wheeled Baskets: These are rectangular baskets with two-wheels on the front and a support at the back. There are two handles on the top by which they can be pushed or pulled. The capacity of such baskets varies from 3 to 5 cft. These are meant for removing the refuse from the narrow lanes and *kachcha* roads and dumping the materials by the side of main roads from where the heavy vehicles remove them to the dumping ground.

3. Trailors: The trailors may be two-wheeled or four-wheeled. They are drawn by tractors. The capacity of trailor varies from 100 to 150 cft. These vehicles remove the refuse from main roads and carry them to the dumping ground. The loading and unloading is done by manual labours.

4. Trucks: The trucks are four-wheeled heavy vehicles. The capacity of the trucks varies from 200 to 250 cft. These vehicles are employed to remove the refuse from the markets and main roads and carry them to the dumping ground. The loading and unloading is done by manual labours or by mechanical device.

2.3 DISPOSAL OF SOLID WASTE

The disposal of the solid waste (i.e. garbage) should be done very carefully so that it may not cause any unhygienic condition. After removal of the refuse, it is taken to the dumping ground. Then suitable method is adopted for the safe disposal. The following are the general methods of disposal:

(a) By trenching
(b) By land filling
(c) By incineration
(d) By pulverisation
(e) By composting
(f) By disposal to sea

(a) By Trenching In this method, trenches are excavated in barren lands far away from the town. The size of the trench may be 12m × 3m × 2m. The garbage is dumped into the trench and levelled properly. The top surface is covered by the excavated earth or by ash (if available). The process of fermentation goes on by the anaerobic bacteria. After about six months the garbage is converted into manure. It is then taken off for use in cultivation. Again, the trench is filled up with fresh garbage. The number of trenches should be such that the process can be continued throughout the year.

(b) By Land Filling This method is very suitable if low-lying areas are available in the locality. In this method, the garbage is dumped in low-lying area phase by phase. The garbage is levelled and the top surface is covered by a blanket of earth or ash. After a considerable time, the garbage is converted into compost soil. Though this soil has got the manurial value; such soil is not taken for cultivation because the garbage is dumped for the purpose of land filling only.

(c) By incineration The process of burning the garbage into ash is known as incineration. The garbage collected from the hospitals may contain bacteria of various diseases. So, such garbage should be burnt in the incinerator (i.e. burning plant) and converted to ash so that the bacteria are completely destroyed. This is a costly method. So, this method is applicable for the towns where sufficient land may not be available for the other methods of disposal.

Again, the garbage collected from other sources may be sorted into two groups—combustible and non-combustible. The combustible garbage may be burnt in incinerator and the non-combustible garbage is buried into the ground.

(d) By Pulverisation The method of grinding the garbage into powder is known as pulverisation. In this method, the garbage is first dried in the sun

for few days by spreading uniformly in the dumping ground. Then the grinding of the dried garbage is done in grinders to convert it to powder. This powder may be used as manure. This is a costly method. So, this method may be adopted in rich countries.

(e) By Composting In this method, the garbage is converted to manure in a mechanical compost plant. This is a hygienic method of garbage disposal. Here, the worthless materials may be obtained as useful materials like fertiliser. The mechanical compost is done in the following way:

(i) Primarily, the materials like paper pieces, cloth pieces, plastic, card board, etc. are separated by any suitable method.
(ii) The ferrous materials are separated by magnetic separator.
(iii) The remaining materials are pulverised.
(iv) The pulverised materials are subjected to fermentation in a mechanical compost plant for about 7 days.
(v) After this period, the materials are converted to compost manure.

(f) By Disposal into Sea In coastal towns, the disposal of garbage into the sea may be applicable. But the garbage should be discharged into the deep sea by studying the current and wave action of the sea so that it may not return to the shore again. This is an easy and cheap method of garbage disposal.

2.4 RECLAMATION OF LAND

Sometimes the garbage may be utilised for the reclamation of land such as filling of ponds, ditches, etc. for the purpose of construction of housing estate, multi-stories buildings, etc. But the filling of the ponds or ditches should be done in scientific way. The following procedure should be adopted for the reclamation of such low-lying areas:

(i) The raw garbage should never be discharged into the ponds or such area because it may create unhealthy situation in the neighbouring area.
(ii) The garbage should be dumped by the banks of the pond and left for about six months.
(iii) During this period, the garbage is converted into soil.
(iv) This soil is levelled gradually towards the centre of the pond.
(v) Stage by stage the pond is filled up from the bank towards the centre.
(vi) When the complete filling is done, the area is left for several years for proper consolidation of the soil.
(vii) After some years, the area may be depressed to some extent. Then, that depression may be filled up by fresh earth or by the soil converted from the garbage.
(viii) The process of reclamation of land may take several years.

2.5 RURAL SANITATION

In village area, the disposal of human excreta is generally done by temporary arrangements such as:

1. Aqua privy
2. Bore-hole privy
3. Tub or pail privy
4. Pit privy
5. Trench privy

Now-a-days, different types of development works for rural sanitation are taken up by the Block Development Authority. Some developments are as follows:

6. Low-cost latrine with septic tank
7. Cesspool

1. Aqua Privy

As shown in Fig. 2.1, the aqua privy consists of three chambers constructed of brick masonry. The pan is placed over the top of first chamber. The pipe of the pan is extended up to 30 cm below the scum (i.e. floating night soil) level. The night soil directly falls to the first chamber. Here, the night soil is decomposed under anaerobic condition. The foul gas passes to second chamber through the opening at the top and finally escapes to the atmosphere by vent pipe. The liquid passes to the second chamber through a large opening at the bottom. In the second chamber, further decomposition takes place by aerobic bacteria. Then the effluent passes to the third chamber through a bent pipe. The third chamber is filled up with clinkers. Finally, the effluent is discharged through the effluent channel. The size of the chambers depends on the number of users.

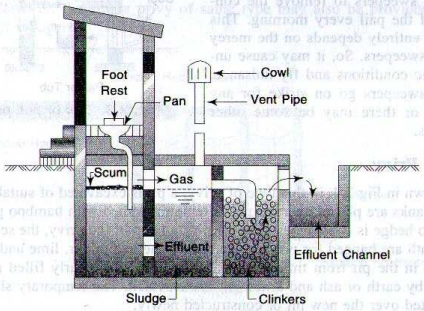


Fig. 2.1 *Aqua privy*

2. Bore-hole Privy

In this type of privy, the latrine is constructed with brick masonry having top cover with asbestos sheet or corrogated tin sheet. A hole is bored outside the latrine by auger. The diameter of the hole is generally 50 cm and depth 5 m. The pan of the latrine is connected to the bore hole by pipe line, as shown in Fig. 2.2. The top of the bore is covered by a slab. The excreta falls to the bore through the pipe. The water is absorbed by the surrounding soil and the excreta accumulated at the bottom. When the bore is nearly filled up, it is closed by dumping earth over it. A new hole is bored by the side of old one and the pipe line is connected to the new bore. After several months, the contents of the old bore may be taken out and the bore may be reused.

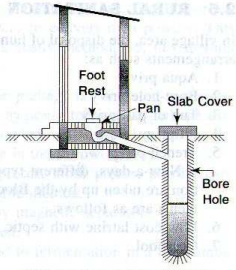


Fig 2.2 *Bore hole privy*

3. Tub or Pail Privy

In this type of privy, a pail or tub is placed below the seat of the latrine. The night soil is collected in the pail. The pail is made of iron sheet in the shape of a box. As shown in Fig. 2.3, a door is provided behind the latrine for the sweepers to remove the contents of the pail every morning. This system entirely depends on the mercy of the sweepers. So, it may cause unhygienic conditions and fly nuisance, if the sweepers go on strike for any reason or there may be some other troubles.

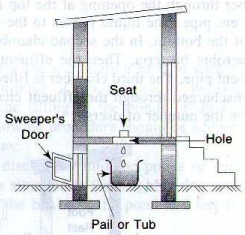


Fig. 2.3 *Tub or pail privy*

4. Pit Privy

As shown in Fig 2.4, in this type of privy, a pit is excavated of suitable size. Two planks are placed over the pit. A temporary shed with bamboo post and bamboo hedge is constructed over the pit. In front of the privy, the screens of jute cloth are hanged for privacy. To reduce the bad odour, lime and ash are thrown in the pit from time to time. When the pit is nearly filled up, it is closed by earth or ash and a new pit is excavated. The temporary shed may be shifted over the new pit or constructed newly.

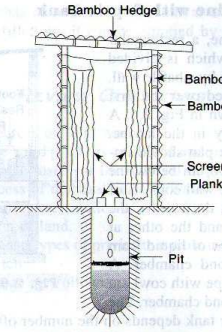


Fig. 2.4 *Pit privy*

5. Trench Privy

In this type of privy, a long trench of required width, depth and length is excavated. The three sides of the trench are covered with bamboo hedge supported by bamboo posts, as shown in Fig. 2.5. Then it is divided into several compartments. The fronts of the compartments are covered by screens of jute cloth for privacy. The top may be open or may be covered by bamboo hedge. The pairs of bamboo pieces are placed side by side as foot rest. These types of privies are purely temporary and mainly provided in fairs or festivals. However, the single privy of same type may also be provided in the house of villagers.

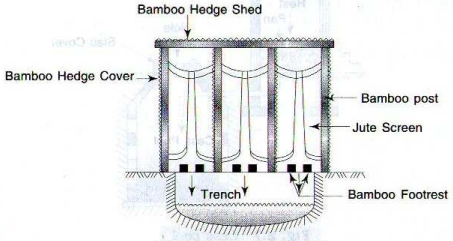


Fig. 2.5 *Trench privy*

6. Low-Cost Latrine with Septic Tank

In this types of latrine, a rectangular tank is constructed which is divided into two compartments by a baffle wall. A latrine is constructed over the first compartment, as shown in Fig. 2.6. A pan is set up suitably in the latrine. The outlet pipe of the pan should immerse to a depth of 30 cm below the scum level. The baffle wall consists of two openings, one at the top for the removal of foul gas and the other at the bottom for the flow of liquid from first chamber to second chamber. A manhole and a vent pipe with cowl are provided over the second chamber. The size of the rectangular tank depends on the number of users. The latrine may be constructed with brick masonry. But the top cover is usually given by asbestos sheet.

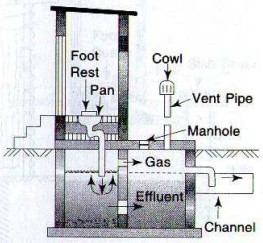


Fig. 2.6 *Low-cost latrine*

7. CessPool

The cesspool is a rectangular or circular chamber which is lined with brick masonry. The pan of the latrine is connected to the cesspool by waste pipe. As shown in Fig 2.7, the wall of the cesspool consists of several zigzag holes so that the water can be absorbed by the surrounding soil. The cesspool is covered with a slab which consists of a small hole for the removal of foul gas. The top slab consists of hooks for its removal at the time of cleaning. When the cesspool is filled up, it can be emptied by manual labours or by pumping.

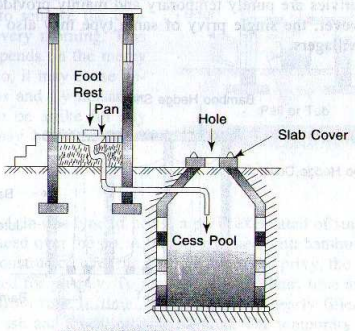


Fig. 2.7 *Cess pool*

Review Questions

1. Enumerate the sources of solid waste.
2. Describe, how the solid waste is collected and removed.
3. What are the vehicles used for the removal of garbage?
4. Describe the process of disposal of solid waste.
5. What do you mean by reclamation of land? State the procedure adopted for the reclamation of land.
6. What are the different types of privies that exist in village area? Describe any two with sketch.
7. Write short notes on the following:
   (a) Aqua privy
   (b) Bore-hole privy
   (c) Pit privy
   (d) Pail privy
   (e) Trench privy
   (f) Cesspool.

3

Systems of Sanitation

3.1 INTRODUCTION

The system of sanitation involves the collection and disposal work of the solid waste (garbage) and liquid waste (sewage) in a systematic way so that the town or city may remain neat and clean and no insanitary condition may arise. Again, the purpose of well planned sanitations is to protect the people from infectious diseases. The refuse should be removed quickly from the town area so that the bad odour, fly nuisance and ugly environment may not arise. The following are the methods of collection and disposal of refuse:

1. Conservancy system
2. Water carriage system

The conservancy system is an old system and is employed in undeveloped towns. But, in modern developed cities the water carriage system is always adopted. Again, the water carriage system may be of three types:

(a) Separate system
(b) Combined system
(c) Partially separate system.

We shall study all the above topics in the followings sections.

3.2 CONSERVANCY SYSTEM

In this system, the garbage, sewage and storm water are collected and disposed of separately by the following ways:

(a) Garbage: The garbage is removed by the wheeled baskets from road side dust-bins, markets, cinema halls, hospitals, etc. and collected in heavy vehicles like trailors or trucks. And then it is conveyed to the dumping ground which should be far away from the town. At the dumping ground, the garbage is separated in two categories—flammable and inflammable. The flammable garbage should be burnt and the inflammable garbage should be dumped in ditches or low-lying areas.

(b) Sewage (i.e. Night Soil): The night soil which is collected in pans at the service latrines of individual houses is removed by the sweepers every day before dawn. The contents of the pans are collected in closed tankers which are drawn by tractors. When the tankers are filled up, they are taken to the night soil trenching ground which should be far away from the town area. The tankers discharge its contents to the night soil pits which are excavated in zig zag manner. Here, the night soil is left for natural treatment by sunshine. It takes too much time for complete decomposition and too much area for disposal.

(c) Storm Water and Sullage: The storm water and sullage are allowed to flow through the open drains and finally allowed to discharge into the river or stream. They do not require any treatment before disposal to natural watercourse.

Disadvantages

The following are the disadvantages of conservancy system:

(i) The compact design of building is not possible, because the lavatory must be constructed separately and away from the main building.
(ii) The decomposition of night soil starts after five hours from the time of production. But the night soil is normally removed after twenty four hours. So, it creates bad odour and fly nuisance around the building.
(iii) The night soil trenching ground requires large area for disposal.
(iv) This system extremely depends on the mercy of sweepers. If the sweepers go on strike for any reason, then the public health will be in danger.
(v) The movement of the night soil vehicles through the main roads or residential area is highly undesirable.
(vi) In rainy season or in floods, the night soil trenching ground may be submerged and it may cause water pollution and may lead to epidemic.
(vii) Initially it seems to be cheap, but the maintenance cost is very high.

The conservancy system has no advantage.

3.3 WATER CARRIAGE SYSTEM

The system in which water is used as a medium for conveying the sewage to the treatment plant and final disposal is known as water carriage system. Plenty of water is required to run this system satisfactorily. Here, the use of human power for collection and disposal of sewage is completely eliminated. The following works are involved in water carriage system:

1. Storm Water: The storm water may be carried separately or may be carried along with sewage through the underground conduits or sewers.

2. Sewage and Sullage: The sewage and sullage are carried by water through the underground sewers. Plenty of water is required for flushing the lavatories and urinals for easy conveyance. The quantity of water should be such that the dilution ratio between solid matters and water becomes very high and the mixture behaves like water. If the water supply remains suspended for a considerable time due to electrical or mechanical failure, then this

3

Systems of Sanitation

3.1 INTRODUCTION

The system of sanitation involves the collection and disposal work of the solid waste (garbage) and liquid waste (sewage) in a systematic way so that the town or city may remain neat and clean and no insanitary condition may arise. Again, the purpose of well planned sanitations is to protect the people from infectious diseases. The refuse should be removed quickly from the town area so that the bad odour, fly nuisance and ugly environment may not arise. The following are the methods of collection and disposal of refuse:

1. Conservancy system
2. Water carriage system

The conservancy system is an old system and is employed in undeveloped towns. But, in modern developed cities the water carriage system is always adopted. Again, the water carriage system may be of three types:

(a) Separate system
(b) Combined system
(c) Partially separate system.

We shall study all the above topics in the followings sections.

3.2 CONSERVANCY SYSTEM

In this system, the garbage, sewage and storm water are collected and disposed of separately by the following ways:

(a) Garbage: The garbage is removed by the wheeled baskets from road side dust-bins, markets, cinema halls, hospitals, etc. and collected in heavy vehicles like trailors or trucks. And then it is conveyed to the dumping ground which should be far away from the town. At the dumping ground, the garbage is separated in two categories—flammable and inflammable. The flammable garbage should be burnt and the inflammable garbage should be dumped in ditches or low-lying areas.

(b) Sewage (i.e. Night Soil): The night soil which is collected in pans at the service latrines of individual houses is removed by the sweepers every day before dawn. The contents of the pans are collected in closed tankers which are drawn by tractors. When the tankers are filled up, they are taken to the night soil trenching ground which should be far away from the town area. The tankers discharge its contents to the night soil pits which are excavated in zig zag manner. Here, the night soil is left for natural treatment by sunshine. It takes too much time for complete decomposition and too much area for disposal.

(c) Storm Water and Sullage: The storm water and sullage are allowed to flow through the open drains and finally allowed to discharge into the river or stream. They do not require any treatment before disposal to natural watercourse.

Disadvantages

The following are the disadvantages of conservancy system:

(i) The compact design of building is not possible, because the lavatory must be constructed separately and away from the main building.
(ii) The decomposition of night soil starts after five hours from the time of production. But the night soil is normally removed after twenty four hours. So, it creates bad odour and fly nuisance around the building.
(iii) The night soil trenching ground requires large area for disposal.
(iv) This system extremely depends on the mercy of sweepers. If the sweepers go on strike for any reason, then the public health will be in danger.
(v) The movement of the night soil vehicles through the main roads or residential area is highly undesirable.
(vi) In rainy season or in floods, the night soil trenching ground may be submerged and it may cause water pollution and may lead to epidemic.
(vii) Initially it seems to be cheap, but the maintenance cost is very high.

The conservancy system has no advantage.

3.3 WATER CARRIAGE SYSTEM

The system in which water is used as a medium for conveying the sewage to the treatment plant and final disposal is known as water carriage system. Plenty of water is required to run this system satisfactorily. Here, the use of human power for collection and disposal of sewage is completely eliminated. The following works are involved in water carriage system:

1. Storm Water: The storm water may be carried separately or may be carried along with sewage through the underground conduits or sewers.

2. Sewage and Sullage: The sewage and sullage are carried by water through the underground sewers. Plenty of water is required for flushing the lavatories and urinals for easy conveyance. The quantity of water should be such that the dilution ratio between solid matters and water becomes very high and the mixture behaves like water. If the water supply remains suspended for a considerable time due to electrical or mechanical failure, then this

system is highly affected. Due to lack of water, the sewer line may be choked or some other troubles may arise.

The installation of water carriage system is very costly, but still it is a scientific and hygienic method of sewage disposal. So, this system is always recommended for modern towns or cities.

Advantages

The following are the advantages of this system:

(i) This system permits compact design of building by accommodating the lavatories in a suitable part of it.
(ii) This is hygienic in nature, as the sewage is carried by underground sewers.
(iii) Less area is required for treatment works.
(iv) The water supplied to the consumers as per demand (i.e. per capita demand) is sufficient for flushing and carrying the sewage. No extra water is required for the sewerage system.
(v) It does not depend on the manual labours except in the case of cleaning of sewers when required.
(vi) There is no chance of any nuisance on the streets.
(vii) The self-cleaning velocity is effective in cleaning the sewers.
(viii) The sludge obtained from sewage treatment plant may be used as manure after proper digestion.

Disadvantages

The following are the disadvantages of this system:

(i) The system is very costly.
(ii) In rainy season, the large volume of sewage flows to the treatment plant which may exceed the normal capacity of the plant.
(iii) In case of any break of water supply, the system is highly affected.

3.4 COMPARISON BETWEEN CONSERVANCY SYSTEM AND WATER CARRIAGE SYSTEM

Table 3.1 lists down the differences between Conservancy and Water Carriage System.

Table 3.1

Sl. No.	*Conservancy System*	*Water Carriage System*
1.	Compact design of building is not possible.	Compact design of building is possible.
2.	Collection and disposal works are done above the ground.	Collection and disposal works are carried out by underground sewers.
3.	It is non-hygienic.	It is hygienic.
4.	It requires no water for conveyance.	It requires large amount of water for conveyance.

(*Contd.*)

Table 3.1 (*Contd.*)

Sl. No.	*Conservancy System*	*Water Carriage System*
5.	The sewage is disposed of without treatment.	The sewage is disposed of after treatment.
6.	Underground sources of water may be polluted.	There is no risk of pollution of underground water.
7.	Large number of labours are required for running the system.	Less number of labours are required for running the system.
8.	It depends on the mercy of sweepers.	It does not depend on the mercy of sweepers.
9.	No skilled labours are required for the maintenance of this system.	Highly skilled labours are required for the maintenance of this system.
10.	Initial cost is low but maintenance cost is high.	Initial cost is high, but maintenance cost is low.
11.	This system is applicable for undeveloped towns.	This system is applicable for developed cities.
12.	Large area is required for treatment and disposal.	Less area is required for treatment and disposal.

3.5 SYSTEMS OF SEWERAGE

The three systems of sewerage have been discussed below:

1. Separate System

This system consists of two sewer lines. One is meant for carrying the sewage to the treatment plant and the other is meant for carrying the storm water. The storm water is directly discharged into the river. After sewage treatment the effluent is also discharged into the river through separate sewer line.

The following are the advantages of this system:

(i) The storm water can be discharged into river directly without any treatment.
(ii) It reduces the load on the treatment plant.
(iii) There is no chance of pollution of river water, as the storm water is not foul in nature.
(iv) If due to change of grade or other inconvenience the sewage is required to pumped, it will impart less load to pumping unit.

The following are the disadvantages of this system:

(i) As two sets of sewer lines are required, it becomes costly.
(ii) The sewer line carrying the storm water remains idle in dry period. So, it may be clogged by garbage in that period.

2. Combined System

This system consists of a single sewer line of large diameter through which the sewage and storm water are allowed to flow and are carried to the treatment plant.

The following are the advantages of this system:

(i) The storm water dilutes the sewage and hence its strength is reduced.
(ii) The self-cleansing velocity is easily achieved.
(iii) Due to larger diameter of sewer, it can be easily cleaned.
(iv) As the single sewer line serves the double function, it becomes economical.

The following are the disadvantages of this system:

(i) The treatment plant is unnecessarily loaded with the combined volume of sewage and storm water. It may exceed the normal capacity of the plant.
(ii) During a heavy storm, the combined sewer may be overflown and it may create trouble for the people at large.
(iii) It creates unnecessary pollution of storm water.

3. Partially Separate System

This system consists of two sewer lines—one is of large diameter for carrying sewage and the other is of smaller diameter for carrying storm water only. When it rains, the storm water, at the beginning, is allowed to flow with the sewage through the larger sewer line. When the rain continues for a long time or it rains heavily, then the excess storm water is diverted to the smaller sewer line to discharge in the river directly. Thus, the load on the treatment plant is controlled and kept within the permissible capacity of the plant.

The following are the advantages of this system:

(i) It reduces the load on the treatment plant and the excess storm water may be safely discharged in the river.
(ii) It helps to maintain the self cleansing velocity in the larger sewer as the storm water is allowed partly.
(iii) The storm water from individual houses may be safely disposed of to the larger sewer.

The following are disadvantages of this system:

(i) The smaller sewer remains idle in dry season.
(ii) If the diversion of storm water is not done at proper time, then it may create unnecessary trouble both in the treatment plant and in the streets.

Review Questions

1. Describe the conservancy system and water carriage system.
2. State the advantages and disadvantages of conservancy system.
3. State the advantages and disadvantages of water carriage system.
4. Compare between the conservancy and water carriage system.
5. What are the various systems of sewerage? Describe the merits and demerits of each.

4

Quantity of Sewage and Storm Water

4.1 INTRODUCTION

The design the suitable section of sewers, it is always necessary to determine the quantity of sewage. The sewage consists of two categories—(a) Domestic or sanitary sewage, (b) Storm water.

The sanitary sewage which flows in dry season is known as dry weather flow (D.W.F.).

The combined flow of sanitary sewage and storm water in rainy season is known as wet weather flow (W.W.F.).

We shall study the methods of determination of dry weather flow and storm water in the following sections.

4.2 FACTORS AFFECTING THE QUANTITY OF SEWAGE OR D.W.F.

The following factors affect the quantity of D.W.F:

1. Rate of Water Supply

The quantity of sewage varies with the rate of water supply. The water supply is not constant throughout the day. It varies with the hours of the day. Again, it varies from day to day and even from season to season. So, to estimate the quantity of sewage, the rate of water supply should be taken into account. Generally, the rate of sewage is assumed equal to the rate of water supply. But, in practice, the rate of sewage should be slightly less than the rate of water supply due to evaporation loss and absorption loss. It is found that the rate of sewage is about 60 to 70 per cent of the rate of water supply.

2. Population

The quantity of sewage depends on the population of the town or city. With the increase in population, the quantity of water also increases. So, the population of the town or city after two or three decades should be ascertained by the suitable method of population forecast.

3. Nature of Area

The quantity of sewage depends on the area of the town such as residential area, industrial area, commercial area, etc. In residential area, the quantity of sewage is taken equal to the quantity of water supplied to consumers. In industrial area, the quantity of water varies with the types of industry. So, the quantity should be determined by actual survey of industry.

4. Infiltration

The subsoil water may percolate in the sewer through the defective joints or cracks in it. The joints may be defective due to poor materials and inferior workmanship. The cracks in the sewer may be formed due to careless handling during conveyances. Cracks may also be formed by the roots of the trees existing along the sewer line. However, it is very difficult to determine the quantity of water infiltrated to sewer. For design purpose, the quantity of water entering the sewer is assumed by considering the length of sewer, number of joints and the diameter of sewer.

4.3 DETERMINATION OF DRY WEATHER FLOW

The quantity of sewage (i.e. D.W.F.) is determined by considering the following three factors:

(i) The total quantity of sewage is taken equal to the quantity of water supply.

(ii) An additional quantity of water is considered for infiltration, private water supply arrangements, commercial and industrial water supply. It is determined by field inspection.

(iii) A subtraction should be made for leakage in pipe line, water consumption in drinking, cooking, washing, etc.

Thus,

Quantity of D.W.F. = (Total quantity of water supply)
+ (Addition due to infiltration etc.)
– (Subtraction due to leakage and consumption)

But, it is found by experiment that the quantity of D.W.F. is equal to 70 to 80 % of the total quantity of water supplied to consumers.

4.4 VARIATION OF FLOW OF SEWAGE

The flow of sewage is directly related to the flow of water supply. As water supply varies from hour to hour, day to day, month to month and season to season, the flow of sewage also varies accordingly. In designing the section

of sewer, the maximum rate of flow is required. The maximum flow occurs early in the morning, i.e. 05–00 hrs. to 07–00 hrs., at noon 12–00 hrs to 14–00 hrs, at evening 18–00 hrs to 20–00 hrs. However, the peak flow of sewage should be ascertained by different observations.

4.5 FACTORS AFFECTING STORM WATER

The following are the factors affecting storm water:

(a) Intensity of Rainfall: If the intensity of rainfall is more, the corresponding storm water (run-off) will be more. Again, if this intensity is low, the corresponding storm water will also be low.

(b) Soil Characteristics: If the catchment area consists of rocky or clayey soil, the storm water will be more. Again, if the soil is sandy, the storm water will be low.

(c) Topography: If the ground slope of the area is steep, the storm water will be more. If the ground is flat and consists of depressions, the storm water will be low.

(d) Shape and Size of Catchment: If the catchment area is large and fan-shaped, the storm-water will be low.

(e) Geological Condition: It the catchment area consists of fissures, cracks, etc. the water losses will be more and hence the storm water will be low.

(f) Vegetative Cover in the Area: If the catchment area consists of plantation, forest area, etc., the storm water will be low.

(g) Weather Condition: If the temperature in the area is high, the evaporation loss will be high and hence the storm water will be low and vice versa.

4.6 DETERMINATION OF RAINFALL INTENSITY

When rainfall records are non-available, the intensity of rainfall is ascertained by the following empirical formulae.

(a) $i = \dfrac{672}{t+10}$ (For storm duration 5 to 20 mins)

(b) $i = \dfrac{1020}{t+10}$ (For storm duration 20 to 100 mins)

(c) $i = \dfrac{3430}{t+18}$ (Where rainfall is frequent, and more than 100 mins)

Here, i = intensity of rainfall in mm/hr.
t = storm duration in mins.

4.7 DETERMINATION OF RUN-OFF COEFFICIENT (K)

When the run-off coefficient is not given, but the nature of surface and impermeability factors of the area are known, then the value of K may be determined. Table 4.1 shows the nature of surface and impermeability factors (p).

Table 4.1

	Surface	Value of P
1.	Residential area with many buildings	0.70 – 0.90
2.	Residential area with detached houses	0.25 – 0.50
3.	Areas with few buildings	0.20 – 0.25
4.	Cultivated areas	0.15 – 0.20
5.	Forest areas	0.10 – 0.20
6.	Rough pasture and barren lands	0.10 – 0.20
7.	Gardens, lawn, parks, etc.	0.05 – 0.10

Now, the run-off coefficient (K) is given by the following expression:

$$K = \frac{a_1 p_1 + a_2 p_2 + ...}{A}$$

where, a_1, a_2 .... = Area of different surfaces.
p_1, p_2 .... = Impermeability factors of those surfaces.
A = Total surface area (a_1, a_2, a_3 .....)

Example 4.1

A catchment area consists of the following surfaces,
(a) Cultivated area = 50 hectares ($p = 0.20$)
(b) Forest area = 30 hectares ($p = 0.10$)
(c) Garden = 5 hectares ($p = 0.05$)
(d) Residential area = 15 hectares ($p = 0.50$)
Find the run-off coefficient of the area.

Solution

Here, total area = 50 + 30 + 5 + 15 = 100 hectares

From, expression, $K = \frac{a_1 p_1 + a_2 p_2 + ...}{A}$

$$= \frac{50 \times 0.20 + 30 \times 0.10 + 5 \times 0.05 + 15 \times 0.50}{100}$$

$$= \frac{20.75}{100}$$

$$= 0.2075.$$

Table 4.2 *Table Showing the Values of K for Different Surfaces*

	Nature of Surface	Value of K
1.	*Urban area*	
	30% impervious	0.40 – 0.50
	50% impervious	0.55 – 0.65
	70% impervious	0.65 – 0.30
	Residential area	0.30 – 0.40

(*Contd.*)

Table 4.2 (*Contd.*)

	Nature of Surface	Value of K
2.	*Rural area*	
	Cultivated area	0.30 – 0.60
	Rough pasture	0.10 – 0.40
	Forest area	0.10 – 0.40
	Area covered by huts	0.20 – 0.30

4.8 COMPUTATION OF STORM WATER

The storm water may be computed by
1. Rational method
2. Empirical formulae

1. Rational Method

In this method, the quantity of storm water is given by the expression,

$$Q = \frac{K \cdot i \cdot A}{360}$$

where, Q = storm water in cumec,
K = Run-off coefficient or impermeability factor
i = Intensity of rainfall in mm/hr.
A = Catchment area in hectares

Example 4.2

A catchment area of 20 sq km. consists of two-third rural and one-third urban area. The rainfall in the area is recorded as 25 mm/hr. Find the quantity of storm water in the area.

Solution:

Total area = 20 sq km = 20 × 1000 × 1000 sqm.
= 2000 hectares (1 hectare = 10.000 m^2)
Rural area = 2000 × 2/3 = 1333.33 hectares
Urban area = 2000 × 1/3 = 666.67 hectares
Intensity of rainfall, i = 25 mm/hr (given)
Assuming run-off coefficient,
K for rural area = 0.30
K for urban area = 0.50

Storm water, $Q = \frac{K \cdot i \cdot A}{360}$

or $$Q = \frac{0.30 \times 25 \times 1333.33 + 0.50 \times 25 \times 666.67}{360}$$

$$= 50.925 \text{ m}^3\text{/sec.}$$

$$= 50925 \text{ lits/sec. } (1\text{m}^3 = 1000 \text{ lits})$$

2. Empirical Formulae

The empirical formulae are based on the experiences and experiments on various conditions, such as nature of surface area, intensity of rainfall, impermeability and the topography of the area concerned. The following are the empirical formulae that are generally adopted:

1. Inglis formula,

$$Q = \frac{123100\,A}{\sqrt{A+10.36}}$$

where, Q = Storm water in lits.sec.
A = Area in km^2

2. Fanning's formula,

$$Q = 3125\,A^{5/8}$$

3. Talbot's formula,

$$Q = 87000\,A^{1/4}$$

4. Ryve's formula,

$$Q = 15\,CA^{2/3}$$

(C = A constant, its value varies from 450 to 675.)

5. Dicken's formula,

$$Q = 14\,CA^{3/4}$$

($C = A$ constant, its value is 250 for large area and 1600 for small area)

Review Questions

1. What are the factors which are considered in determining the quantity of dry weather flow?
2. Describe the procedure of determining the quantity of dry weather flow.
3. Explain the rational method of determining storm water.
4. State some empirical formulae for calculating the intensity of rainfall.
5. State some empirical formulae which are adopted for calculating the quantity of storm water.
6. How is impermeability factor determined?

5

Design of Sewers

5.1 INTRODUCTION

In sanitary engineering, the design of sewer is most important, because the success of sewerage system depends on it. After estimating the quantity of sewage and storm water, the diameter of main sewer, branch sewer, intercepting sewer, etc. should be designed properly. The design period should be taken as 30 years according to the population forecast for that period. The minimum and maximum velocities of flow of sewage should be maintained by providing suitable gradient so that the conditions of non-silting and non-scouring may be achieved.

In this chapter, we shall study all the topics relating to sewer such as section of sewer, materials of sewer, joints in sewer, ventilation of sewer, laying of sewer, etc.

5.2 MINIMUM AND MAXIMUM VELOCITY

The sewage contains suspended particles to a considerable amount. So, the minimum velocity should be such that the silting of those particles in sewer may not occur. Such minimum velocity is known as self-cleansing velocity. The self-cleansing velocity depends on the amount and size of suspended particles. Again, the amount of suspended particles depends on dilution factor. Considering the above factors, the minimum velocity should be achieved by providing suitable gradient in the sewer. Generally, the self-cleansing velocity varies from 70–100 cm per sec.

The maximum velocity should also be taken into account. The suspended particles may impart scouring action to the inner surface of sewer and may damage the sewer section. So, the maximum permissible velocity should be such that no scouring action may taken place. Such maximum velocity is known as non-scouring velocity. The non-scouring velocities for some sewer material are given on next page.

Table 5.1

Materials	*Non-scouring Velocity in cm/sec.*
Brick lined sewer	150 to 250
Cement concrete sewer	250 to 300
Stone ware sewer	300 to 450

5.3 EMPIRICAL FORMULAE FOR THE DESIGN OF SEWERS

1. Mean velocity by Chezy's formula.

   Velocity, $V = C\sqrt{mi}$ m/sec.

   where, V = mean velocity in m/sec.
   C = Chezy's constant.
   m = hydraulic mean depth in m.
   i = longitudinal slope or hydraulic gradient.

   The Chezy's constant (C) can be obtained by Bazin's formula or Kutter's formula.

2. Bazin's formula.

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{m}}}$$

or
$$C = \frac{87}{1 + \frac{K}{\sqrt{m}}}$$

where C, m = as above
K = Bazin's constant.

Table 5.2 *Bazin's Constant*

Surface	*Value of K*
Very smooth surface	0.109
Brick and concrete surface	0.290
Rubble masonry surface	0.833

3. Kutter's Formula.

$$C = \frac{23 + \frac{0.00155}{i} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{i}\right)\frac{N}{\sqrt{m}}}$$

where, C, m, i = As above.
N = Roughness coefficient or rugosity factor or Kutter's constant.

Table 5.3 *Rugosity Factor (N)*

Surface	*Value of N*
Smooth surface	0.010
Concrete surface	0.012
Stone ware pipe	0.013
Brick or stone masonry	0.017
Earthen channel	0.025

4. Mean velocity by Manning's formula.

   Velocity, $V = \frac{1}{N} \times m^{2/3} \times i^{1/2}$

   where, V, N, m and i = As above

5. Mean Velocity by crimp and Bruge's formula.
   Velocity, $V = 83.50 \times m^{2/3} \times i^{1/2}$
   where, V, m, i = As above.

6. Mean velocity by Hazen and Willian's formula.
   Velocity, $V = 0.85 \times C \times m^{0.63} \times i^{0.54}$
   where, V, m, i = As above,
   C = a coefficient. (given in Table 5.4)

Table 5.4 *Value of Coefficient C*

Type of Materials	*Value of C*
Cast-iron pipe	100
Brick sewer	100
Stone ware pipe	110
Cement lined pipe	110
Pipes with very smooth inside surface	140

Problem 5.1

Calculate the velocity of flow and the discharge through a sewer of diameter 1 m laid at a gradient of 1 in 500. Assume the sewer running full. Use Manning's formula with N = 0.012.

Solution

We know, Manning's formula

$$V = \frac{1}{N} \times m^{2/3} \times i^{1/2}$$

Given, Coefficient of rugosity, $N = 0.012$

Gradient, $i = \frac{1}{500}$, diameter $d = 1$ m.

Now, Area $A = \frac{\pi d^2}{4}$

Wetted perimeter, $P = \pi d$ (running full)

Hydraulic mean depth, $m = \frac{A}{P} = \frac{\pi d^2}{4 \times \pi d} = \frac{d}{4}$.

$\therefore \quad m = \frac{1}{4} = 0.25$ m

Velocity by Manning's formula

$$V = \frac{1}{0.012} \times (0.25)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$
$$= 1.479 \text{ m/sec.}$$

Discharge, $Q = A \times V$

$$= \frac{\pi \times (1)^2}{4} \times 1.479$$
$$= 1.16 \text{ m}^3\text{/sec.}$$

Problem 5.2

Design the diameter of combined sewer having the following data:

1. Area = 500 hectares
2. Population = 1,00,000
3. Water supply = 150 lits/capita/day
4. Intensity of rainfall = 15 mm/hr
5. Impermeability factor = 0.50
6. Maximum permissible velocity = 2.0 m/sec.

Assume reasonable data if necessary.

Solution

Assuming 80% of water supply appears as sewage.

Average discharge $= \frac{1,00,000 \times 150 \times 0.80}{24 \times 60 \times 60} = 139$ lits/sec.

Assuming maximum discharge as 1.5 times, the average discharge.

Max. discharge = 139 × 1.5 = 208.5 lits/sec,

$\therefore$ D.W.F = 208.5 lits/sec

Storm water is given by

$$Q = \frac{K\,i\,A}{360}$$
$$= \frac{0.50 \times 15 \times 500}{360}$$
$$= 10.41 \text{ m}^3\text{/sec}$$
$$= 10410 \text{ lits/sec.}$$

where $K = 0.50$

$i = 15$ mm/sec

$A = 1000$ hectares

Combined discharge = 208.5 + 10410

= 10618.5 lits/sec.

i.e. $Q = 10.618$ m^3/sec. (1m^3 = 1000 lits)

Assuming, the sewer running full at maximum velocity

$$Q = A \times V, \quad A = \frac{Q}{V} = \frac{10.618}{2} = 5.309 \text{ m}^2$$

where A = C/s area of sewer

V = 2m/sec. permissible Velocity

Let, d = diameter of sewer

So, $\frac{\pi d^2}{4} = 5.309$

or $d = \frac{\sqrt{5.309 \times 4}}{\pi}$

$\therefore \quad d = 2.6$ m.

Problem 5.3

A sewer of diameter 1m is to be laid along a road with self-cleaning velocity as 90 cm/sec. Find the gradient of the sewer line to achieve the said velocity considering the sewer running half filled. Assume Bazin's constant = 0.30.

Solution

Given diameter = 1 m

Bazin's constant = 0.30

C/s Area $= \frac{\pi d^2}{4}$

Wetted perimeter $p = \frac{\pi d}{2}$

Hydraulic mean depth $= m = \frac{\pi d^2}{4} \times \frac{2}{\pi d}$

$$= \frac{d}{2} = \frac{1}{2} = 0.5 \text{ m.}$$

Value of Chezy's constant, C is found out by Bazin's formula.

$$C = \frac{157.6}{1.81 \times \frac{K}{\sqrt{m}}} = \frac{157.6}{1.81 \times \frac{0.30}{\sqrt{0.50}}} = 70.54$$

From Chezy's formula,

$V = C\sqrt{mi}$

$0.90 = 70.54 \times \sqrt{0.50} \times \sqrt{i}$ (Self-cleaning velocity = 0.90 cm/sec)

or $\sqrt{i} = \frac{0.90}{70.54 \times \sqrt{0.50}} = 0.018$

$\therefore \quad i = .0003 = \frac{1}{3333.3}$

So, the gradient is 1 in 3333.33.

5.4 SECTION OF SEWER

Generally, the circular shaped sewers are adopted, the advantages of circular sewers are:

(i) The perimeter of circular sewer is the least with respect to the sewer of other shape.
(ii) The inner surface is smooth hence the flow of sewage is uniform and there is no chance of deposition of suspended particles.
(iii) The circular sewers are easy to construct.

However, non-circular shaped sewers are also adopted for the following reasons:

(i) They can be constructed in such a convenient size and shape so that a man can enter the sewer for cleaning, repairing, etc.
(ii) The process of construction is easy.
(iii) The structural strength is more.
(iv) The cost of construction is low.

The following are the non-circular sewers that are commonly adopted:

(a) Basket-Handle Section: In this sewer, the outer surface is circular. The inner surface is divided into two portions. As shown in Fig. 5.1, the upper portion resembles a basket-handle and the lower portion is like a channel.

During dry season, the sewage flows through the lower portion and during monsoon, the combined sewage flows through the full section.

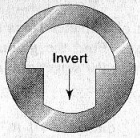


Fig. 5.1 *Basket-handle section*

(b) Egg-shaped Section: The egg-shaped section sewers may be of two types—normal egg-shaped and inverted egg-shaped. Both the sections are suitable for carrying D.W.F. and combined sewage. Figure 5.2 shows both types of egg-shaped section.

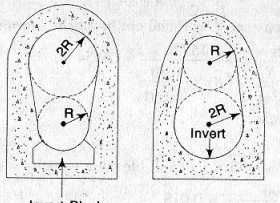


Fig. 5.2 *Egg shaped section*

(c) Horse-Shoe Section: This type of sewer is constructed for carrying heavy discharge. This is like a tunnel and resembles a horse-shoe, as shown in Fig. 5.3. The size is so large that the maintenance works within the sewer are very easy.

Fig. 5.3 *Horse-shoe section*

(d) Parabolic Section: As shown in Fig. 5.4, the upper surface of the sewer is in the shape of a parabola and the invert is in the shape of an ellipse. This type of sewer is suitable for carrying small discharge.

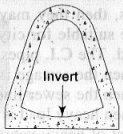


Fig. 5.4 *Parabolic section*

(e) Rectangular Section: This type of sewer can be easily constructed. These are suitable for large sewers to carry heavy discharge of sewage. The maintenance works are easy in this section. Figure 5.5 shows a rectangular section.

(f) U-shaped Section: As shown in Fig. 5.6, this type of sewer resembles the letter 'U'. This sewer is suitable for carrying heavy discharge. The maintenance works are easy in this section. (Fig. 5.6).

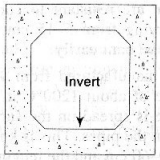


Fig. 5.5 *Rectangular section*

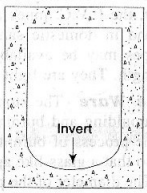


Fig. 5.6 *U-shaped section*

5.5 MATERIAL OF SEWER

The following material are used for sewers:

(a) Asbestos Cement Asbestos cement is a mixture of cement and asbestos fibre. Pipes are manufactured from this mixture over a rotating mandrel in uniform thickness. The diameter of the pipes varies from 5 cm to 100 cm. These pipes are very light and can be handled and transported easily and they are not affected by salts, acid and corrosive materials. The cutting, drilling, fitting and joining of the pipes can be done easily. These pipes are suitable for domestic sanitary fittings.

(b) Bricks The bricks are used for constructing large size sewers. The brick work should be done by cement mortar (1:5) and the inner surface is

plastered by rich cement morter (1:3) accompanied by neat cement polish. To prevent infiltration, the outer surface should also be plastered. The brick work can be done easily as bricks are available at all places at a cheap price. But, the sewer section should always be rectangular.

(c) Cast-iron The cast-iron can withstand high internal pressure and can bear external load. These are very heavy and difficult to transport. These pipes should be handled carefully, otherwise cracks may be formed due to sudden shock. These are resistant to corrosion, but if the sewage contains sulphates, then they may be affected by corrosion. However, the cast-iron pipes are suitable for city roads and in places where high external loads are suspected. The C.I. pipes are suitable for the following conditions:

(i) When the sewage is conveyed under high pressure.
(ii) When the sewer line is to be laid in exposed position or in suspension.
(iii) When heavy load is suspected to come over the sewer due to the movement of heavy vehicles.

(d) Cement Concrete The pre-cast cement concrete pipes are extensively used in the construction of sewers. The pre-cast pipes are manufactured with mild steel re-inforcement by centrifugal process. These are known as 'Hume pipes'. The diameter of hume pipes varies from 10 cm to 200 cm and length varies from 1m to 3m. These are strong and smooth. But these are very heavy and difficult to transport. The pipes are joined by collar joints.

(e) Plastic Previously, the plastic pipes were not used for carrying sewage. Now, the P.V.C. pipes are used for sewer lines for carrying industrial sewage and in domestic sanitary fitting. These are resistant to corrosion. These pipes may be available in diameter varying from 5–15 cm and of longer length. They are light in weight and can be bent easily.

(f) Stone Ware The stone ware pipes are manufactured from vitrified clay by moulding and burning to a temperature of about 1200°C in a kiln. During the process of burning, sodium chloride is spread on the surface of the pipe so that a glass-like appearance comes on the pipes. This is known as glazing. The diameter of the pipe varies from 10–60 cm and the length varies from 90–120 cm. These are resistant to corrosion and abrasion. But these are brittle and may be damaged if handled carelessly. These are generally used in domestic sanitary fittings.

5.6 JOINTS IN SEWERS

The following are the common joints in sewers:

(a) *Bell and Spigot Joints:* See Part-I, Section 4.8 (i)
(b) *Collar Joints:* See Part-I, Section 4.8 (ii)
(c) *Flexible Joint:* See Part-I, Section 4.8 (v)
(d) *Expansion Joint:* See Part-I, Section 4.8 (iii)
(e) *Flanged Joint:* See Part-I, Section 4.8 (iv)

5.7 SECTION OF SURFACE DRAINS

The following sections are adopted for the construction of surface drains:

1. Rectangular section
2. Semi-circular section
3. U-shaped section
4. V-shaped section.

1. Rectangular Section

In this type, two vertical walls are constructed on a concrete foundation. The thickness of the walls depends on the size of the drain. Again, the depth and width of the drain depends on its required carrying capacity. The inner surface is plastered with rich cement mortar (1:3) and finished with neat cement polish. The bottom edges are rounded-off for smooth running of the sewage as shown in Fig. 5.7. This section is suitable for carrying high discharge.

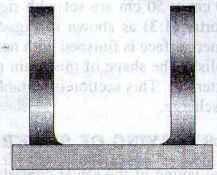


Fig. 5.7 *Rectangular section*

2. Semi-circular Section

Figure 5.8 shows the semi-circular section. It is constructed by casting plain cement concrete (1:3:6) in the shape of a semi-circle. The inner surface is finished with neat cement polish over a rich cement plaster (1:3). The radius (r) of the drain depends on the carrying capacity. These are suitable for low discharge.

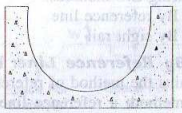


Fig. 5.8 *Semi-circular section*

3. U-Shaped Section

In this type of drain, the bottom surface is made curved and it is constructed with plain cement concrete (1:3:6). The two sides are constructed with brick work. As shown in Fig. 5.9, the sides are vertical and the bottom is curved. So, it resembles the letter 'U'. This is practically a combination of rectangular and semi-circular section. The inner surface is finished with neat cement polish. This is suitable for medium discharge.

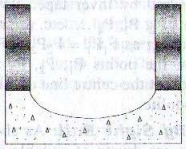


Fig. 5.9 *U-shaped section*

4. V-shaped Section

In this type of drain, the bed block is constructed with plain cement concrete. The sides are made sloping and the brick soling is done according to the slope. Then thick cement mortar (1:6) is laid and levelled properly to form a bed. On this prepared bed, concrete blocks of size 50 cm × 50 cm are set with rich cement mortar (1:3) as shown in Fig. 5.10. The inner surface is finished with neat cement polish. The shape of this drain resembles letter '*V*'. This section is suitable for low discharge.

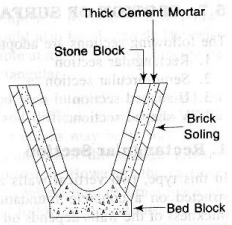


Fig. 5.10 *V-shaped section*

5.8 LAYING OF SEWER

The laying of the sewer consists of the following steps:

1. Marking of the Alignment

The alignment (i.e. centre line) of the sewer is marked along the road with a theodolite and inver tape. The centre line may be marked according to the following two methods:

(a) By reference line
(b) By sight rail

(a) By Reference Line: Figure 5.11 explains the method of reference line. In this method, a reference line is marked along any side of the busy roads by the-odolite and inver tape. The points F_1F_2 .... are on the reference line. The starting point (P_1) of the centre line is marked with a peg. Then the distance F_1P_1 is measured by inver tape. Now the other points P_2, P_3, P_4 .... etc. are marked pegs by taking as $F_1P_1 = F_2P_2 = F_3P_3$ .... etc. Thus, the points P_1, P_2, P_3 ... etc. will represent the centre line of the sewer. This centre line may be checked by the theodolite.

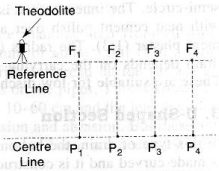


Fig. 5.11 *Reference line*

(b) By Sight Rail: As shown in Fig. 5.12, in this method, two vertical posts are driven at suitable distance apart. Then by ranging through a the-odolite the centre line is marked with nail on a sight rail which is fixed on the vertical posts. The sight rail should be fixed in such a way so that its upper edge just coincides with the line of sight. The centre line of the sewer is transferred to the ground by plumb bob with respect to the nail. The

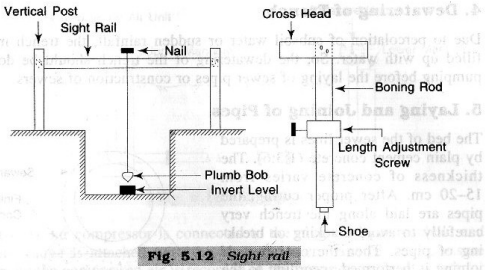


Fig. 5.12 *Sight rail*

distance between the upper edge of sight rail and the invert level is determined and noted on the sight rail for finding the exact invert level by boning rod. The length of boning rod is adjusted according to the height as noted in sight rail. The cross-head is levelled with the upper edge of sight rail and the bottom edge indicates the invert level.

2. Excavation of Trench

Figure 5.13 explains the way of marking for the excavation of trench. The width of the trench (W) is marked on the road which is about 15 cm more than the external diameter or external dimension of sewer. At the probable point of joining, the width of the trench (W_1) is made 60 cm more than the external diameter and a length (L) of about 60 cm is kept clear for the operation of joining. The position of manhole is also marked according to its dimension.

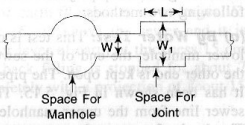


Fig. 5.13 *Excavation of trench*

Now, the excavation is started according to the marking. The invert level is fixed by boning rod, which is adjusted according to the height written in sight rail. The cross-head of boning rod is levelled with the upper edge of sight rail and the verticality of rod is maintained by plump bob. The bottom edge of the shoe will indicate the invert level. In this way, the excavation is continued.

3. Bracing of the Trench

Timber bracings or sheet piling should be provided on both sides of the trench so that it may not collapse due to rain or any reason during the process of laying and joining.

4. Dewatering of Trench

Due to percolation of subsoil water or sudden rainfall, the trench may be filled up with water. So, the dewatering of the trench should be done by pumping before the laying of sewer pipes or construction of sewers.

5. Laying and Joining of Pipes

The bed of the sewer lines is prepared by plain cement concrete (1:3:6). The thickness of concrete varies from 15–20 cm. After proper curing, the pipes are laid along the trench very carefully to avoid cracking or breaking of pipes. Then the operation of joining is performed according to the recommended joint as per the type of pipe material: After completion of joining, both sides of the pipe are finished with concrete, as shown in Fig. 5.14.

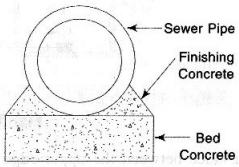


Fig. 5.14 *Concrete bed*

6. Testing of Leakage

The leakage in the pipe joints or any point in the pipe line is tested by the following two methods:

(a) By Water Test: This test is carried out between two manholes. In the lower manhole, the end of the sewer is plugged and in the upper manhole, the other end is kept open. The pipe end of previous section is kept plugged. It has been shown in Fig. 5.15. Then the water is allowed to flow in the sewer line from the upper manhole until the sewer is completely filled up. The depth of water in the upper manhole is raised up to 1 m above the sewer. The water is allowed to stay in the sewer for a week. Then the sewer line is inspected to detect the leakage by observing any sweating. If the leakage is detected, it is rectified immediately.

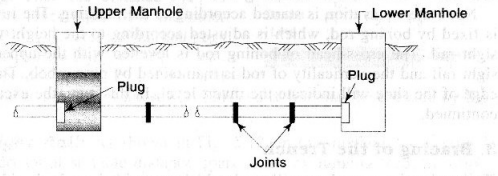


Fig. 5.15 *Water test*

(b) By Air Test: Figure 5.16 explains the procedure of air test. This test is carried out for large diameter sewer. The pipe ends of both the manholes are

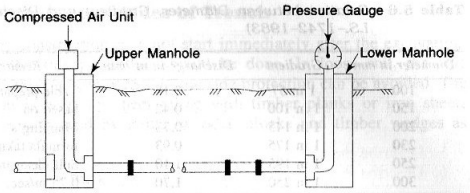


Fig. 5.16 *Air test*

plugged. An air compressor is connected to the plug of upper manhole and pressure gauge is attached with the plug of lower manhole. The pressure exerted by the compressed air is recorded in the pressure gauge. It is left for few hours. If the pressure drops below the permissible limit, then it is an indication of leakage. The exact point of leakage is found out by applying soap solution which will show bubbles at the point of leakage. If leakage is detected, it should be removed immediately.

7. Back Filling

After the completion of testing and removal of leakage (if any), the trenches are filled up with the excavated earth. The earth filling is done in stages. At first, the earth is laid to a thickness of 15 cm above the sewer and it is watered and rammed gently. Then, further layer of earth of thickness 15 cm is laid and rammed properly. Then the back filling is stopped for about 7 days. Finally, the trench is filled up completely with a projection of about 15 cm above the ground level.

5.9 RELATION BETWEEN DIAMETER, GRADIENT, VELOCITY AND DISCHARGE

Table 5.5 *Table Prepared Based on Crimp's Formula*

Diameter in mm	*Gradient for velocity = 0.75 m/sec.*	*Gradient for velocity = 0.90 m/sec.*	*Gradient for velocity = 1.05 m/sec.*
150	1 in 150	1 in 150	1 in 78
225	1 in 265	1 in 180	1 in 135
300	1 in 385	1 in 270	1 in 195
375	1 in 520	1 in 355	1 in 265
450	1 in 660	1 in 460	1 in 340
525	1 in 820	1 in 570	1 in 415
600	1 in 970	1 in 680	1 in 500
675	1 in 1100	1 in 790	1 in 580
750	1 in 1300	1 in 910	1 in 670
900	1 in 1650	1 in 1200	1 in 850
1050	1 in 2100	1 in 1450	1 in 1050
1200	1 in 2500	1 in 1700	1 in 1250

Table 5.6 *Relation between Diameter, Gradient and Discharge (As per I.S.–1742–1983)*

Diameter in mm	*Gradient*	*Discharge in m^3/min*	*Remark*
100	1 in 57	0.18	Table prepared
150	1 in 100	0.42	based on
200	1 in 145	0.73	Manning's
230	1 in 175	0.93	formula taking
250	1 in 195	1.10	Self cleansing velocity as
300	1 in 250	1.70	0.75 m/sec.

Table 5.7 *Relation between Diameter, Gradient and Discharge (As per I.S.–1742–1983)*

Diameter in mm	*Gradient*	*Discharge in m^3/min*	*Remark*
100	1 in 5.6	0.59	Table prepared
150	1 in 9.7	1.32	based on
200	1 in 14	2.40	Manning's formula
230	1 in 17	2.98	where it is not possible
250	1 in 19	3.68	to provide ruling gradient
300	1 in 24.5	5.30	and self-cleansing velocity

5.10 REQUIREMENTS OF SURFACE DRAIN

The following should be the requirement of surface drain:

(a) The self-cleansing velocity should be developed with minimum discharge.
(b) Sufficient free board should be adopted.
(c) The surface should be smooth so that it can be cleaned easily.
(d) It should be strong to resist scouring action.

5.11 CONSTRUCTION OF SURFACE DRAIN

The construction of surface drain should be done according to the following stages:

Stage 1. Marking the Centre Line of Drain

The centre line of the surface drain is marked on the ground on both sides of the road. The width of the drain is marked by spade.

Stage 2. Excavation of Trench

The trench is excavated according to the width and depth. The excavated earth is heaped on one side of excavation leaving sufficient space between the heaps for supplying materials of construction.

Stage 3. Protection of Sides of Trench

Sometimes the construction may not start immediately after the excavation. In that case, the side protection should be done. In loose soil, the side protection is a must but, in hard soil, the side protection can be avoided. The side protection is done by sheet piling with timber planks or iron sheets which may be supported by struts, wooden blocks and timber wedges as shown in Fig. 5.17.

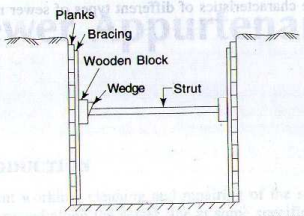


Fig. 5.17 *Side protection of trench*

Stage 4. Preparation of Subgrade

The subgrade is prepared by ramming a layer of sand (about 15 cm). Then a layer of brick bats (15 cm) is laid over the sand layer and rammed perfectly to make the surface compact and levelled.

Stage 5. Construction

Over the compact subgrade a layer of cement concrete (1:3:6) is laid to a thickness of 15 cm. The sides of the drain may be constructed with brick masonry with cement mortar (1:6) or may be constructed with re-inforced cement concrete (1:2:4). The inside surface of the drain should be plastered with rich cement mortar and finished with neat cement polish. Curing should be done for 7 days.

Stage 6. Earth Filling

After proper curing, the hollow spaces on both sides of the drain are filled with excavated earth and rammed lightly.

REVIEW QUESTIONS

1. How is the centre line of sewer marked on the ground?
2. How is the leakage of sewer tested?

3. Write short notes on:
   (a) Bucket-handle section
   (b) Egg-shaped section
   (c) U-shaped section
   (d) Horse-shoe section
4. What are the different types of surface drains? Describe them with sketches.
5. Describe the sewer joints with sketch.
6. Describe the characteristics of different types of sewer materials.

6

Sewer Appurtenance

6.1 INTRODUCTION

For the efficient working, cleaning and repairing of the sewer, some structures are constructed along the sewer line at some specific points which are known as sewer appurtenance. The following are the important structures:

1. Manhole
2. Drop manhole
3. Lamp hole
4. Catch basin
5. Street inlet
6. Grease and oil trap
7. Flushing tanks
8. Inverted siphon
9. Ventilating shaft
10. Storm regulator

6.2 MANHOLE

A hole which is made from the ground level to the underground sewer for the entrance of men for inspection, cleaning and repairing works, is known as a manhole. The manholes are provided at specified interval, change of direction, change of grade, junction points, etc.

Depending upon the depth, the manholes may be shallow, normal and deep. The depth below 1 m is considered as normal manhole and the depth above 1.5 m is considered as deep manhole.

As shown in Fig. 6.1, the deep manhole is constructed with brick masonry over a concrete foundation. The bottom portion is wider which is known as working chamber and the upper portion is narrower which is known as access shaft. The access shaft is made narrow by corbelling or by providing R.C.C. slab as offset.

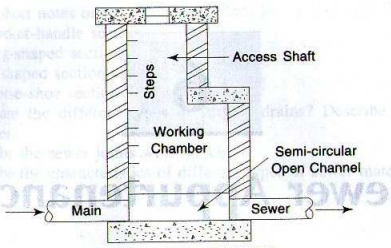


Fig. 6.1 *Manhole*

The following are the components of a deep manhole:

(a) Access Shaft The access shaft may be rectangular or circular. The minimum size of the rectangular shaft should be 90 cm × 100 cm and minimum diameter of circular shaft should be 90 cm. The height of the shaft depends on the height of the working chamber. The shaft serves the purpose of removing the debris from the sewer and acts as a passage for the workers to conduct the maintenance works.

(b) Working Chamber The purpose of working chamber is to provide sufficient space for the workers for cleaning the sewer and for conducting maintenance works. The height of the working chamber should be 2 m so that a worker can work comfortably. The size of rectangular chamber should be 120 cm × 150 cm and diameter of circular chamber should be 120 cm.

(c) Steps The steps are provided on the wall of the manhole for the entry and exit of the workers. The steps may be made of cast iron which are embedded in the wall in zig-zag manner. If the manhole is too deep, then it is better to provide a ladder instead of steps.

(d) Invert The main sewer just ends at both sides of the manhole. A semi-circular section channel is constructed to connect the two ends so that there is an open channel within the manhole. The sides of the channel are made sloping with concrete. This is known as benching. The sediments or obstructions in the sewer are pushed towards the manhole and these are collected in the open channel from where those are taken out through the access shaft.

(e) Manhole Cover Generally, the manhole cover is circular and made of cast-iron. The cover should be thick and heavy and stable enough to resist the wear and tear caused by moving vehicles. The diameter of the cover should be 60 cm to 75 cm so that a man can enter the manhole easily. The frame of the cover is embedded in road pavement and the cover is placed on the groove firmly.

6.3 DROP MANHOLE

A manhole which is constructed to connect the high level branch sewer to the low level main sewer by vertical dropping pipe is known as drop manhole. As shown in Fig 6.2 a branch sewer passes at higher level and the main sewer runs at lower level. So the sewage will fall in the main sewer in the form of a spring. This will cause much inconvenience to the workers at the working chamber. So, the end of the branch pipe is plugged and a vertical dropping pipe is taken from the branch pipe and connected to the manhole near the bottom to allow the sewage to fall in main sewer smoothly. Steps are provided in zigzag manner for the entry and exit of the workers.

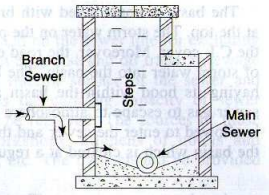


Fig. 6.2 *Drop manhole*

6.4 LAMP HOLE

A hole or opening which is provided in a sewer line for lowering a lamp inside is known as Lamp hole. It is a vertical pipe made of stoneware which is connected to the sewer by a Tee-joint. At the top a box-line compartment is made which carries a cast-iron cover. The cover may be solid or perforated as shown in Fig. 6.3.

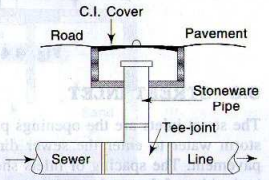


Fig. 6.3 *Lamp hole*

The construction of lamp hole is advisable for the following conditions:

(i) When the spacings of regular manholes are at longer interval.
(ii) When it is difficult to construct a regular manhole.
(iii) When a change of direction or change of grade comes in the sewer line.

The following are the functions of lamp hole:

(i) By removing the C.I. cover, an electric lamp is inserted into the sewer. If the sewer is clear, the light will be visible from the adjacent manholes. If there is any obstruction, the light will not be visible from the manholes. Then the operation of clearing will be done accordingly.
(ii) For clearing the obstruction, the flushing devices may be applied through the lampholes.
(iii) If the C.I. cover is made perforated, then it will serve the purpose of ventilation of sewer or the removal of sewer gases.

6.5 CATCH BASIN

A catch basin is a rectangular chamber constructed along the sewer line to allow the storm water to enter the sewer by eliminating the silt, grit, etc. at the bottom of the basin.

The basin is constructed with brick masonry with a perforated C.I. cover at the top. The storm water on the pavement directly enters the basin through the C.I. cover. Moreover, the road curb is provided with grating for the entry of storm water into the basin. The basin is connected to the sewer by a pipe having its hood within the basin as shown in Fig. 6.4. This prevents the sewer gas to escape to atmosphere through the basin. The clear storm water is allowed to enter the sewer and the sediments are arrested at the bottom of the basin which is cleared at a regular interval or when required.

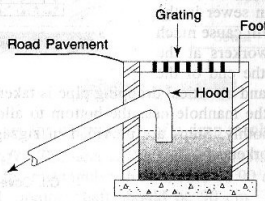


Fig. 6.4 *Catch basin*

6.6 STREET INLET

The street inlets are the openings provided by the side of roads to allow the storm water to enter the sewer directly without accumulating on the road pavement. The spacing of inlets should be 20 m and should be provided on both sides of the road.

The inlets may be vertical or horizontal. A box-like compartment is constructed with brick masonry. In vertical type, a grating is provided on the road curb just at the edge of foot path, as shown in Fig. 6.5(a). In horizontal types, a perforated cover is placed on the top of the chamber, as shown in Fig. 6.5(b).

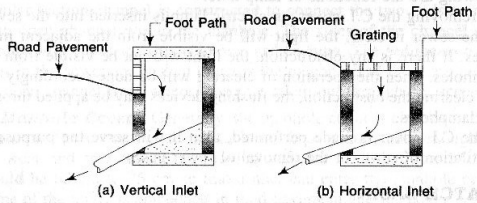


Fig. 6.5 *Street inlet*

6.7 GREASE AND OIL TRAP

The traps or chambers which are constructed on the sewer line for excluding grease and oil from the sewage are known as grease and oil traps. If sewage contains grease and oil, it sticks to the interior surface of the sewer and ultimately get hardened. This decreases the carrying capacity of sewer gradually. So, those oily materials must be removed. The sources of those materials are automobile repairing workshops, kitchens of hotels and restaurants, oil manufacturing industries, etc. The traps should be provided by surveying the location of those areas.

Figure 6.6 shows the grease and oil trap. The trap is a rectangular chamber having baffle walls at the middle. The sewage containing grease and oil enters the chamber through the inlet grating. The sand, grit, etc. are accumulated at the bottom of the first chamber. The grease and oil floats over the second chamber. The sediments and the floating substances (grease and oil) should be removed from time to time.

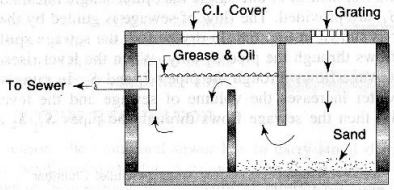


Fig. 6.6 *Grease and oil trap*

6.8 FLUSHING TANK

The flushing tank is a device by which the water is released automatically at some interval for flushing the sewer line. This device is required at places where self-cleansing velocity in the sewer cannot be obtained due to some reason. Figure 6.7 shows a flushing tank. It consists of a U-tube encased in a compartment. The longer arm is extended in the water tank and a bell or hood is placed over the free end. The shorter arm is connected to the sewer line through a straight pipe. Initially, the water level in the U-tube stands at a-a′. The water is supplied to the tank through a flow regulator.

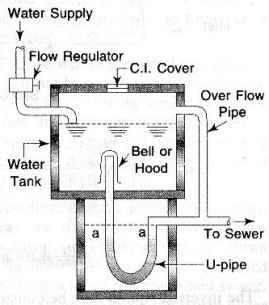


Fig. 6.7 *Flushing tank*

When the water level in the tank increases, the water level in the bell also increases. Ultimately, a stage comes when the siphonic action starts and the water rushes through the sewer clearing all the sediments. The water supply is so regulated that the siphonic action starts at some interval. The siphonic action stops when the water level comes below the bell mouth. After discharging water the level in the U-tube stands again at the line 'a-a'. The capacity of the tank should be quite adequate for flushing the sewer line properly.

6.9 INVERTED SIPHON

During the laying of sewer line, a position may come when it is not possible to maintain the same gradient due to some obstructions such as crossing of railway line, roads, etc. In that case, the inverted siphon should be provided. The condition of siphonic action is that the pipe or tunnel should run full all the time. But in dry season the discharge may not be sufficient to run the inverted siphon full. So, instead of one single line, three single lines, i.e. three lines (S_1, S_2 and S_3) are provided. The flow of sewage is guided by the weirs (W_1, W_2 and W_3), as shown in Fig. 6.8. In dry period, the sewage spills over the weir W_1 and flows through the pipe S_1 only. When the level rises above the weir W_2, the sewage flows through the pipes S_1 and S_2. In rainy season, when the storm water increases the volume of sewage and the level rises above the weir W_3, then the sewage flows through the pipes S_1, S_2 and S_3 simultaneously.

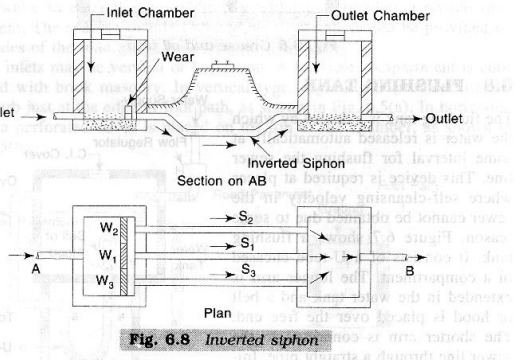


Fig. 6.8 *Inverted siphon*

The inverted siphon may be constructed by cast-iron pipes or hume pipes. If the length of siphon is too great, a vent pipe should be provided in the siphon to prevent air locking.

6.10 VENTILATING SHAFT

The ventilating shaft is provided for the ventilation of sewer. Various gases are produced in the sewer due to the decomposition of organic matters. Some gases may be harmful to workers. Some gases may be highly explosive and may cause explosion in the sewer; some gases may be corrosive and may cause corrosion to sewer pipes. So, by constructing ventilating shaft in the sewer line, these gases are removed. The shaft may be provided at an interval of 100 m. The shaft may be made of C.I. pipes or hume pipes of diameter 15 cm. A cowl is provided on the top. The base of the shaft is wide and secured in concrete foundation. The shaft is directly connected to the sewer or manhole. The height of the shaft should be such that the foul gases may not cause any danger to human health. Figure 6.9 shows a ventilating shaft.

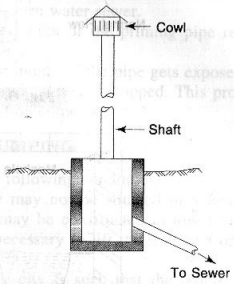


Fig. 6.9 *Ventilating shaft*

6.11 STORM REGULATOR

In dry season, the combined sewer has to carry small discharge of sewage (i.e. dry weather flow). But in rainy season the discharge increases due to storm water. Sometimes, the intensity of rainfall becomes so great that the quantity of storm water is enormously increased. During that period, the discharge may exceed the normal capacity of the combined sewer and it may even exceed the permissible capacity of the treatment plant. So, some devices are adopted for the diversion of the excess storm water to the river or stream. The following are the common devices:

(a) Leaping Weir This arrangement is done within a manhole. It consists of an adjustable weir and lip which are adjusted in such a way so that the permissible discharge of sewage is allowed to flow over the crest of the weir and directly fall in the sanitary sewer. When the discharge is increased enormously due to heavy rainfall, the excess storm water jumps over the crest of the weir and falls on the lip which carries the storm water to the river or stream. Figure 6.10 explains the working of leaping weir.

(b) Overflow Weir In a manhole, the combined sewer is made as an open channel. The channel consists of a weir on one side. Sometimes, weirs may be provided on both sides. In normal condition, the combined sewage flows through the open channel. But, when the quantity of storm water is increased due to heavy rainfall, it exceeds the normal capacity of the combined sewer. In that case the excess water spills over the weir and falls on the storm water sewer which carries the water to the outfall, as shown in Fig. 6.11.

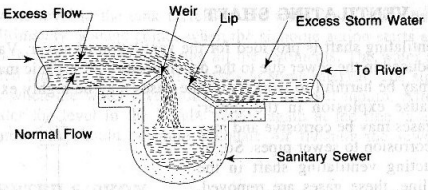


Fig. 6.10 *Leaping weir*

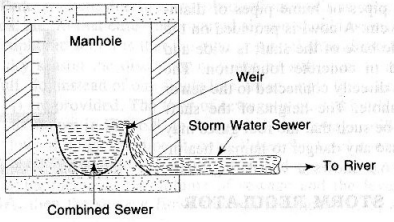


Fig. 6.11 *Over flow weir*

(c) Siphon Spillway In this system, the upper end of the siphon is connected to the combined sewer and the lower end is connected to the storm water sewer. As shown in Fig. 6.12, a priming pipe is connected between the combined sewer and the throat of the siphon. The function of the siphon spillway is as follows:

(i) The throat of the siphon is kept at the maximum permissible level in the combined sewer.

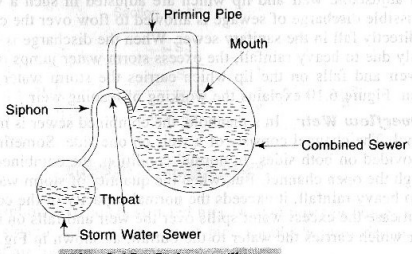


Fig. 6.12 *Siphon spillway*

(ii) The siphonic action does not start when the level of the combined sewage is just below the maximum level.

(iii) When the level in the combined sewer goes above the throat of siphon and the mouth of priming pipe is submerged, the air in the pipe is sucked by the flowing water and suddenly siphonic action starts. Then the excess water starts flowing to the storm water sewer.

(iv) The siphonic action continues till the mouth of the priming pipe remains under water.

(v) After discharging the excess water, the mouth of the pipe gets exposed and air enters the pipe. Then the siphonic action is stopped. This process is repeated when the above condition comes again.

6.12 NECESSITY OF SEWAGE PUMPING

The pumping of sewage is necessary in the following conditions:

(a) The whole portion of a town or city may not be situated in a level ground. Some portion of sewer line may be constructed in low level areas. In that condition, pumping is necessary to lift the sewage from the lower sewer line to higher sewer line;

(b) When the general slope of a town or city is such that the required gradient cannot be maintained;

(c) In case of underground shopping complex or when basement is provided in a building;

(d) When the treatment plant is constructed at a site which is higher than the level of main sewer line.

6.13 SEWAGE PUMPS

The following types of pumps are provided for the pumping of sewage:

(a) Centrifugal Pump.
(b) Reciprocating Pump
(c) Air Pressure Pump or Ejector.

The centrifugal and reciprocating pumps are described in Chapter 5 of Part-I—Water Supply.

Air Pressure Pump or Ejector

There are many ejectors manufactured by different companies out of which 'Shone's Air Ejector' is commonly used which is described below:

Components Figure 6.13 shows a Shone's ejector. It consists of the following components:

(a) A cast iron cylindrical chamber in which a spindle is provided. The spindle again carries two cups—upper and lower.

(b) Two reflux valves are provided, one at the entrance side and other at the exit side.

(c) A lever is pivoted at a suitable point and it carries a counter-weight at one end.

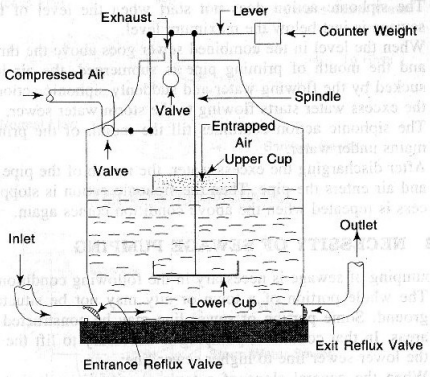


Fig. 6.13 *Shone's ejector*

(d) Two ball valves are attached with the lever—one at the mouth of air compressor and the other at the mouth of exhaust pipe. The valves are adjusted in such a way that when one valve closes, the other valve opens simultaneously during the up and down motion of the spindle.

Working: The working principle is as follows:

(a) At the beginning, the compressed air valve and exit reflux valve remain closed and the entrance reflux valve and exhaust valve remain open.
(b) The sewage enters the chamber through the entrance valve and the air inside the chamber escapes through the exhaust pipe. The level of sewage goes on increasing gradually.
(c) When the level of sewage reaches the bottom of upper cup, the air inside the cup is entrapped. On further increase in sewage level the entrapped air exerts pressure on the spindle. The spindle is lifted up and the lever action starts.
(d) The lever is pivoted in such a way that the exhaust valve is closed and compressed air valve is opened simultaneously.
(e) The compressed air forces the sewage to flow through the outlet pipe by opening the exit reflux valve.
(f) The flow of sewage continues until the sewage level falls below the bottom of upper cup.
(g) The pressure on the spindle is released and by lever action the exhaust valve is opened and compressed air valve is closed. The sewage again flows to the chamber. This process is repeated automatically.

Advantages The advantages of an Air Pressure Pump or ejector are:

(a) The operation of the ejector is automatic and hence no supervision is required.
(b) The primary treatment of sewage is not necessary.
(c) There is no chance of clogging.
(d) No pumping station is required.

Disadvantages The only disadvantage of this system is that it is not suitable for high discharge and its efficiency is low.

Review Questions

1. Describe the component parts of a manhole.
2. What is drop manhole? What are its objects? How is it constructed?
3. What is a flushing tank? Describe with a sketch.
4. Describe a grease and oil trap with sketch.
5. What is a inverted siphon? Describe its function with sketch.
6. What is a lamphole? Mention its objects. Describe a lamp hole with sketch.
7. Mention the objects of storm regulator. Name the types of storm regulators.
8. Explain the working of leaping weir with a neat sketch.
9. Describe an overflow weir with sketch.
10. Explain the working of siphon spillway with sketch.
11. Write short notes on:
    (a) Street inlets
    (b) Automatic flushing tank
    (c) Inverted siphon
    (d) Leaping weir
    (e) Drop manhole
    (f) Grease and oil trap

7

Characteristics of Sewage

7.1 INTRODUCTION

The study of characteristics of sewage plays an important role in sanitary engineering, because the process of treatment should be determined according to the characteristics. Again, the treatment should be such that the effluent can be disposed of to the natural water sources safely. The characteristics are divided into three categories:

1. Physical characteristics
2. Chemical characteristics
3. Biological characteristics

Before carrying out the testing of sewage, the sampling should be done properly. The testing involves the following:

1. Physical tests
2. Chemical tests
3. Biological tests

Again, the treatment of sewage involves the determination of following factors:

1. Biochemical oxygen demand (B.O.D.)
2. Chemical oxygen demand (C.O.D.)

In this chapter, the characteristics and examinations are described stage by stage.

7.2 DEFINITION OF SOME TERMS

1. Algae The unicellular plants which contain chlorophyll are known as Algae. The algae absorb carbon-dioxide and release oxygen by the process of photosynthesis.

2. Fungi The fungi are also unicellular plants, but they do not contain chlorophyll. They are colourless and can decompose starch, sugar, cellulose, fats, proteins etc. The yeast is a kind of fungi.

3. Protozoa These are unicellular worms. They can destroy pathogenic bacteria, but they survive by eating other bacteria.

4. Bacteria The microscopic unicellular organisms are known as bacteria. The bacteria may be harmful or harmless to human being. But the presence of bacteria is essential for the decomposition of sewage.

5. Pathogenic Bacteria The bacteria which are responsible for water-borne diseases like cholera, dysentry, typhoid, etc. are known as pathogenic bacteria.

6. Non-pathogenic Bacteria The bacteria which are harmless to human being are known as non-pathogenic bacteria.

7. Aerobic Bacteria The bacteria which require light and free oxygen for their survival are known as aerobic bacteria.

8. Anaerobic Bacteria The bacteria which do not require light and free oxygen for their survival are known as anaerobic bacteria.

9. Facultative Bacteria The bacteria which can survive with or without the presence of light and free oxygen are known as facultative bacteria.

10. B-coli The pathogenic and non-pathogenic bacteria form a group which is known as bacillus coli group. This group is briefly known as B-coli. This group of bacteria is present in the intestines of all living animals.

11. E-coli The most common type of coliform group is Escherichia coli which is briefly known as E-coli. The germs of E-coli are discharged from the faeces (i.e. stool) of human being.

7.3 PHYSICAL CHARACTERISTICS

The following are the physical characteristics of sewage:

1. Specific Gravity The specific gravity of sewage is slightly more than that of water.

2. Colour The fresh sewage has yellowish grey colour. As the decomposition goes on, the colour also goes on changing. It becomes black when the sewage attains the septic stage. The colour of the industrial sewage depends on the waste products.

3. Odour The fresh sewage has soapy or oily odour. But the stale or septic sewage has offensive odour due to hydrogen sulphide and other gases.

4. Temperature The temperature of sewage is slightly higher than the temperature of water supplied. While passing through the conduits the temperature rises and the bacterial activities start.

5. Turbidity The turbidity of sewage is due to the suspended particles.

6. Solids The sewage contains 0.1% of solid matters and 99.9% of water. The solid matters may be suspended, dissolved or in colloidal states. Again, the solids may be inorganic or organic. The inorganic solids are grits, sand, etc. and organic solids are cellulose, sugar, starch, etc.

7.4 CHEMICAL CHARACTERISTICS

The following are the chemical characteristics of sewage:

1. The fresh sewage is alkaline in nature, and the septic sewage is acidic in nature.

2. Organic Compounds

(i) Nitrogeneous compounds: It include urea, proteins, amino acids, etc.
(ii) Non-nitrogeneous compounds: It include fats, soaps, carbohydrates, etc.

3. Inorganic Compounds It include sand, gravel, grit, etc.

4. Colloidal Matters It include silt, clay, etc.

7.5 BIOLOGICAL CHARACTERISTICS

The sewage contains the following bacteria and microorganisms:

1. Bacteria The bacteria may be of the following types:

(i) Pathogenic Bacteria: This is the root of all water-borne diseases.

(ii) Non-pathogenic Bacteria: This is practically harmless to human being.

(iii) Aerobic Bacteria: It helps the decomposition of sewage in oxidation ponds, lagoons, etc.

(iv) Anaerobic Bacteria: It helps the decomposition of sewage in septic tank, cesspool, etc.

(v) Facultative Bacteria: This bacteria has no function in sewage treatment.

2. Microorganisms The microorganism like algae, fungi and protozoa help the process of decomposition of sewage by photosynthesis or by breaking the organic compounds.

7.6 SAMPLING OF SEWAGE

The following are the procedures of collecting the sample of sewage for the various laboratory tests:

(i) The samples of sewage are collected at an interval of one hour during the day.
(ii) The sampling bottles should be of capacity 100 c.c. to 150 c.c.
(iii) The bottles should be cleaned properly before taking the samples.
(iv) The bottle should be closed tightly by stopper as soon as it is filled up.
(v) The bottle should be kept in a cool place.
(vi) The samples should be collected from different points of the sewer.
(vii) The analysis of sewage should be started within two hours from the time of collection.
(viii) The date, time and place of collection of sample should be noted on the bottles.

7.7 NECESSITY OF TESTING OF SEWAGE

The following points may be considered as the reasons for the necessity of testing of sewage:

(i) To determine the strength, character and the stage of sewage for adopting proper treatment of sewage and the method of disposal.
(ii) To regulate the treatment plant according to variation in the nature of sewage.
(iii) To recommend the type of treatment to be adopted for the particular sample of sewage.
(iv) To adopt optimum treatment to sewage to obtain the effluent of high quality.

7.8 PHYSICAL TESTS

The physical tests include the following observations:

1. Colour The colour indicates the nature of sewage whether it is fresh or septic. The light brown colour indicates fresh sewage. The dark or black colour indicates septic. The colour of industrial sewage depends on the discharge of industrial wastes. The colour of the sewage can be easily identified by naked eye. So, the shade of colour should be properly observed and designated accordingly and noted against the sample. However, to designate the colour the platinum cobalt scale may be used.

2. Turbidity The turbidity of sewage is due to the suspension of fine particles. It is measured by turbidity rod or jackson's turbidimeter. Turbidity is expressed as ppm (i.e. part per million). It is also expressed as mg/lit. Practically, turbidity is phenomenon of resistance offered by water or liquid to the passage of light. The standard unit of turbidity is given by one part of finely divided silica in million parts of distilled water.

3. Temperature The temperature cannot be controlled by any treatment. So, the test for the temperature has no significance in sewage analysis. Still, the temperature of the sample of sewage should be noted as the biological activities depend on the temperature. At greater temperature the biological activities are high and viscosity is low. When viscosity is low, the efficiency of treatment plant is more.

4. Odour The odour indicates whether the sewage is fresh or septic. Some industrial wastes also impart odour to the sewage. However, the odour may be tested in laboratory in terms of threshold number and noted against the sample. The number may be helpful to know the stage of sewage and necessary treatment may be given accordingly.

7.9 CHEMICAL TESTS

The chemical tests involve the determination of following factors:

1. Total solids
2. Chlorine demand

3. Dissolved oxygen
4. Biochemical oxygen demand
5. Chemical oxygen demand
6. Nitrogen
7. pH-value
8. Grease, oil and fats.

1. Total Solids

It is very essential to know the quantity of total solids in sewage. Because, it helps to know the rate of deposition of sludge in the primary sedimentation tank and at the same time it is possible to indicate the organic and inorganic substances in sewage which help in the sewage treatment. The amount of total solids are found out as follows:

A known amount of sewage (say 1 lit) is taken and the water is evaporated at 100°C. The residue is dried properly and weighed. The weight of the dry residue represents the total solids. Again, the total solids may be of two types:

(i) Volatile solids.
(ii) Suspended solids.

(a) Volatile solids The dried total solids (as obtained previously) are heated or ignited in electric furnace. After ignition, the remaining solids are weighed. The loss of weight will indicate the volatile solids present in sewage. The volatile solids are due to the presence of organic matters.

(b) Suspended Solids The solids which settle down due to the phenomenon of hydraulic subsidence are known as suspended or settleable solids. The amount of settleable solids are found out as follows:

A conical glass vessel, known as Imhoff cone, is taken. Figure 7.1 shows an Imhoff cone. The capacity of the cone is 1 lit and it is graduated in ml from the bottom. The sample of sewage of quantity 1 lit is taken in the cone and it is allowed to rest for about two hours. The amount of solids settled at the bottom of the cone is read from the graduation. Now to know the exact amount of settleable solids the moisture from the sediment is removed and weighed.

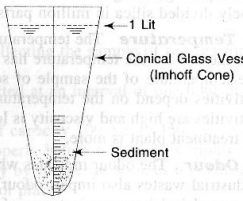


Fig. 7.1 *Imhoff cone*

2. Chlorine Demand

A requisite amount of chlorine is required to break up the organic matters present in sewage and for killing the pathogenic bacteria. The necessity of this chlorine is known as chlorine demand. It is found out by the process of break-point chlorination (as described in chapter—Chlorination).

3. Dissolved Oxygen

The oxygen in dissolved state in sewage is required for the living organisms to perform their metabolic process. Again, it is very essential in precipitating and oxidising inorganic substances. The amount of dissolved oxygen depends on the temperature of sewage. However, the determination of dissolved oxygen in sewage is a very complicated process. It may be determined in the laboratory by using the reagents manganese sulphate, concentrated sulphuric acid, starch indicator, sodium thiosulphate, etc.

4. Biochemical Oxygen Demand (B.O.D.)

The function of oxygen is to oxidise the inorganic and organic matters in sewage. Again, the presence of oxygen is required for the survival of organisms. These organisms are responsible for the aerobic decomposition of organic matters. When the oxygen is exhausted, the anaerobic decomposition starts which is indicated by foul smell. Now, the quantity of oxygen required for the biological decomposition of sewage under aerobic condition should be worked out. This demand of oxygen is known as biochemical oxygen demand or B.O.D. (Details of B.O.D. is given in art. 7.13)

5. Chemical Oxygen Demand (C.O.D.)

The amount of oxygen which is required for the chemical decomposition of organic matters in sewage is known as chemical oxygen demand (C.O.D.). The tests for C.O.D. is required to know the contents of organic matters which should be oxidised by chemical oxidising agents. (Details of C.O.D. is given in art 7.14)

6. Nitrogen

Nitrogen may be present in sewage in the forms of free ammonia, albuminoid ammonia, nitrates or nitrites. The various forms of nitrogen indicate the following stages:

(i) The presence of free ammonia indicates that the sewage is stale.
(ii) The presence of albuminoid ammonia indicates the undecomposed nitrogenous matters.
(iii) Nitrites indicate the stage of conversion of organic matters to stable form.
(iv) Nitrates indicate the stable form of nitrogenous matters. The determination of all the above factors are the guidelines for the results achieved by the sewage treatment plant.

7. pH-value

The pH-value of sewage is to be determined to know its nature—whether it is acidic or alkaline. The treatment methods depend on the pH-value. At the beginning, the fresh sewage is alkaline in nature, but it is converted to acidic nature after few hours. The bacteria cannot survive in acidic sewage. However,

the pH-value of sewage is determined by electrometric method or colourimetric method. (As described in Chapter 6—Part-I)

8. Grease, Fat and Oil

The presence of grease, fat and oil are undesirable in sewage, as it may disturb the working of trickling filter and may form some deposits in sewers and treatment plants. Initially, these are eliminated by traps and prevented from entering the sewer. But, still some traces may remain in sewage. The quantity of oily substances is determined by evaporating the sample of sewage. Then the remaining substances are dissolved in ether. When ether is evaporated, it gives the quantity of grease, fat and oil present in sewage.

7.10 BIOLOGICAL TESTS

The biological tests are carried out to know the presence of bacteria, fungi, algae, protozoa, etc. The presence of some bacteria is essential for the decomposition of sewage. But, the presence of pathogenic bacteria indicates the degree of pollution in sewage. So, necessary measure should be taken to kill the pathogenic bacteria. The presence of fungi, algae and protozoa is necessary for the treatment of sewage. The biological tests are carried out by microscope and by studying the biological character of the bacteria. The helpful bacteria are allowed to develop under the favourable conditions. They form colonies and help to decompose the organic substances present in sewage.

7.11 DECOMPOSITION OF SEWAGE

The function of bacteria in sewage is to break up the complex organic compounds into simple and stable compounds. The decomposition of sewage by bacteria may be of the following two types:

1. Aerobic Decomposition

Aerobic decomposition is caused by the aerobic bacteria in presence of plenty of oxygen. This type of bacteria cannot survive without oxygen. This decomposition is also known as oxidation. In this process, the aerobic bacteria break up the organic matters and the organic matters are oxidised to form stable compounds. After oxidation the compounds like carbon dioxide, nitrates, sulphates etc. are formed. The aerobic decomposition occurs in contact beds, oxidation ponds, trickling filters, etc.

2. Anaerobic Decomposition

Anaerobic decomposition is caused by the anaerobic bacteria in absence of oxygen. This type of bacteria can survive without oxygen. This decomposition is also known as putrefaction. The anaerobic bacteria break up the complex organic compounds and convert them into solids, liquids and gases. After

putrefaction, the compounds like humas (black residue), ammonia methane, hydrogen sulphide, etc. are formed. The anaerobic decomposition occurs in septic tanks, Imhoff tanks and sludge digestion tanks.

7.12 CYCLES OF DECOMPOSITION

As per universal law, the matters remain constant, only the change of state occurs. Similarly, in biochemical reactions some cycles of decomposition are developed like an endless chain. As for example, organic matters are broken up by biochemical reactions and simple compounds are formed. The plants consume those compounds for their growth and formation of food grains. Again, the animals or human beings consume those plants or food grains for their growth. Ultimately, the organic matters return from the waste products of animals or human beings. It is found that the cycles of decomposition may be of three types:

1. Carbon cycle
2. Nitrogen cycle
3. Sulphur cycle

1. Carbon Cycle

The decomposition of organic carbonaceous matters forms carbon dioxide. The plants consume the carbon dioxide by the process of photosynthesis. Thus plant carbohydrates, fats and proteins are formed. Animals consume the plants and thus the animal fats and proteins are formed. Again, the waste products of animals form the organic carbonaceous matters. In this way, the cycle of carbon is completed. The carbon cycle is also shown in Fig. 7.2.

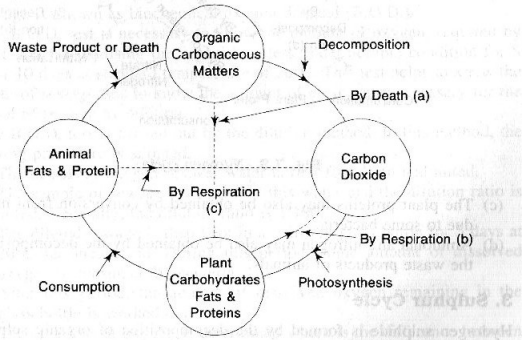


Fig. 7.2 *Carbon cycle*

The actual cycle is shown by firm line and the dotted lines show the subsidiary cycle of carbon as for example

(a) Death of plants may be converted to organic carbonaceous matters.
(b) The plants exhaust carbon dioxide at night by respiration.
(c) The animals also exhaust carbon dioxide by respiration.

2. Nitrogen Cycle

As shown in Fig. 7.3 the decomposition of organic nitrogeneous matters forms ammonia and nitrogen. Then by the process of nitrification, ammonia and nitrogen are transformed into nitrite, nitrate and free nitrogen. Plants consume these products and plant proteins are formed. Animals consume the plants and thus animal proteins are formed. The waste products or death of animals form the organic nitrogeneous matters again. Thus the nitrogen cycle is completed. The following are the subsidiary cycles:

(a) Death of plants forms organic nitrogeneous matters.
(b) Nitrate nitrogen may be converted to ammonia and nitrogen by denitrification.

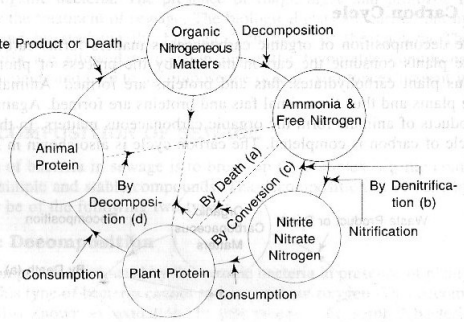


Fig. 7.3 *Nitrogen cycle*

(c) The plant proteins may also be obtained by conversion from nitrogen due to some bacteria.
(d) Ammonia and nitrogen may also be obtained by the decomposition of the waste products of animals.

3. Sulphur Cycle

Hydrogen sulphide is formed by the decomposition of organic sulphurous matters. Sulphates are formed by the oxidation of hydrogen sulphide. As shown in Fig. 7.4, plants consume the sulphates and thus plant proteins are

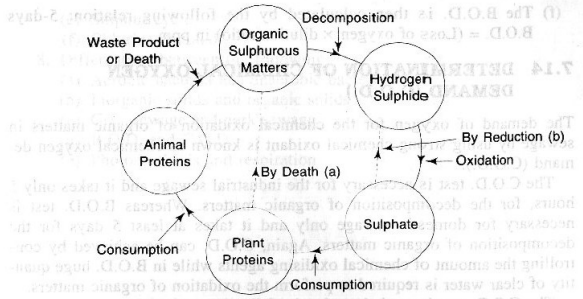


Fig. 7.4 *Sulphur cycle*

Again, the waste products or death of animal form the organic sulphurous matters to complete the cycle. This cycle is known as sulphur cycle. There are two subsidiary cycles:

(a) The death of plants may be converted to organic sulphurous matters.
(b) The sulphates may be transformed to hydrogen sulphide by the process of reduction.

7.13 DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND (B.O.D.)

The demand of oxygen for the biochemical decomposition of organic matters in sewage is known as biochemical oxygen demand (B.O.D.).

The B.O.D. test is necessary to know the amount of oxygen, required by the bacteria for oxidising the organic matters under aerobic condition for 5 days or 10 days at standard temperature of 20°C. This test helps to know the strength of sewage and to know the amount of clear water necessary for the disposal of sewage by dilution.

The B.O.D. test is carried out by the dilution method. In this method, the following procedure is adopted:

(a) The dissolved oxygen in clear water is first found out and noted.
(b) The sample of sewage is diluted by this water and the dilution ratio is noted. Generally, the dilution ratio is 1:100.
(c) The diluted sewage is then kept in an airtight glass bottle for 5 days at 20°C for incubation. During this period, some amount of dissolved oxygen is consumed by bacteria.
(d) After this period, the amount of dissolved oxygen remaining in the glass bottle is worked out.
(e) Then the loss of oxygen is determined which is the difference between the dissolved oxygen at the beginning and dissolved oxygen remaining at the end.

(f) The B.O.D. is then calculated by the following relation: 5-days B.O.D. = (Loss of oxygen × dilution ratio) in ppm.

7.14 DETERMINATION OF CHEMICAL OXYGEN DEMAND (C.O.D.)

The demand of oxygen for the chemical oxidation of organic matters in sewage by using strong chemical oxidant is known as chemical oxygen demand (C.O.D.).

The C.O.D. test is necessary for the industrial sewage and it takes only 5 hours, for the decomposition of organic matters. Whereas B.O.D. test is necessary for domestic sewage only and it takes at least 5 days for the decomposition of organic matters. Again, C.O.D. can be achieved by controlling the amount of chemical oxidising agents while in B.O.D. huge quantity of clear water is required to perform the oxidation of organic matters.

The C.O.D. test is carried out by the following procedure:

(a) A known amount of sample of sewage is taken in a pot.
(b) A known amount of potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4) are added to the sample.
(c) The mixture is kept for about three hours.
(d) During this period, a chemical reaction takes place to produce CO_2 and H_2O.
(e) After the reaction, the remaining amount of potassium dichromate is determined by titration with ferrous ammonia sulphate $Fe(NH_4)_2(SO_4)_2$ solution.
(f) The consumption of dichromate indicates the amount of oxygen required for the oxidation of organic matters.

Review Questions

1. Describe the physical properties of sewage.
2. Why is the analysis of sewage necessary? Describe the method of collecting sample of sewage.
3. Discuss the physical tests of sewage.
4. Discuss the chemical tests of sewage.
5. (a) Define B.O.D.
   (b) Discuss how it is determined.
   (c) What is its importance in sewage analysis?
6. What is C.O.D? How is it determined? What is the difference between C.O.D. and B.O.D.?
7. Write short notes on:
   (a) Aerobic decomposition
   (b) Anaerobic decomposition
   (c) Carbon cycle
   (d) Nitrogen cycle

   (e) Sulphur cycle
   (f) Chlorine demand
8. Differentiate between the following:
   (a) Aerobic bacteria and anaerobic bacteria
   (b) Inorganic solids and organic solids
   (c) Grey sewage and dark sewage
   (d) B.O.D. and C.O.D.
   (e) Photosynthesis and respiration

8

Primary Treatment of Sewage

8.1 INTRODUCTION

The sewage contains various suspended, floating and oily substances. By primary treatments these substances are removed from the sewage so that the working of the sedimentary treatment units may be easy and there is no disturbances in the operation of those units. The units of the primary treatments are as follows:

(a) Screens
(b) Grit chamber
(c) Detritus tank
(d) Skimming tank
(e) Primary sedimentation tank.

8.2 FLOW DIAGRAM OF PRIMARY TREATMENT

The units in Fig. 8.1. are arranged according to the sequence of primary treatment.

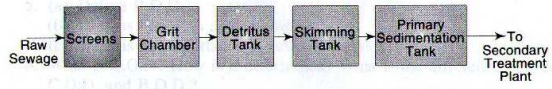


Fig. 8.1 *Flow diagram of primary treatment*

Functions of Units

1. Screens To eliminate large floating matters.

2. Grit Chamber To eliminate large size organic and inorganic matters.

3. Detritus Tank To eliminate finer organic and inorganic matters.

4. Skimming Tank To eliminate grease, oil, soap, etc.

5. Primary Sedimentation Tank To eliminate fine colloidal particles.

8.3 SCREENS

The screen is the first unit of primary treatment plant. The function of screen is to remove all the floating debris like wood pieces, cloth and paper pieces, decayed fruits and vegetables, etc. If these floating matters are not eliminated, it may choke the pipe lines or it may cause damage to the pumping unit.

Construction The screens may be constructed of M.S. bars or rods, gratings, wire meshes or perforated plates. The M.S. bar screen is made by placing parallel bars with spacings according to the following types:

(a) Coarse Screen The spacings of bars are more than 40 mm centre to centre.

(b) Medium Screen The spacing are less than 40mm.

(c) Fine Screen The spacings vary from 1.5 mm to 6 mm.

The screens may be fixed or movable. As shown in Fig. 8.2, the inclination of the screen varies from 30° to 60°. The screens are placed at designed inclination in an oblong rectangular chamber. The ends of the chamber are tapered. It is constructed with brick masonry. The inner surfaces are plastered and finished with neat cement polish. A perforated rectangular channel is provided at the top of the screen for the collection of floating debrises.

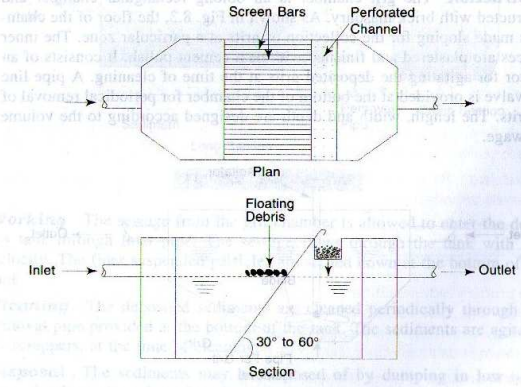


Fig. 8.2 *Screen*

Working The raw sewage is allowed to enter the chamber through the inlet pipe. The floating debris are obstructed by the screen and collected near it. The sewage containing the other suspended materials passes through the screen and is taken to the next unit (i.e. grit chamber).

Cleaning The debris may be cleaned by manual labours or mechanical device. In manual system, the debris are raked by rakers and collected in the perforated channel from where these are disposed of. In mechanical device system, a raking arm (like crane) is provided which collects the debris at regular interval and throws in a collecting basin from where these are disposed of.

Disposal The debris may be disposed of by the following way:

(a) Dumping The debris are dumped in low-lying areas far away from the locality.

(b) Burning After drying, the debris are burnt to ashes.

(c) Composting Good quality manure may be obtained by composting the debris in compost plant.

8.4 GRIT CHAMBER

The function of grit chamber is to remove the inorganic substances like grit, sand and other suspended materials. The velocity of flow in the grit chamber is kept low so that a detention period is available for the settlement of the above substances.

Construction The grit chamber is an oblong rectangular chamber and constructed with brick masonry. As shown in Fig. 8.3, the floor of the chamber is made sloping for the collection of grits at a particular zone. The inner surfaces are plastered and finished with neat cement polish. It consists of an agitator for agitating the deposited grits at the time of cleaning. A pipe line with valve is provided at the bottom of the chamber for periodical removal of the grits. The length, width and depth are designed according to the volume of sewage.

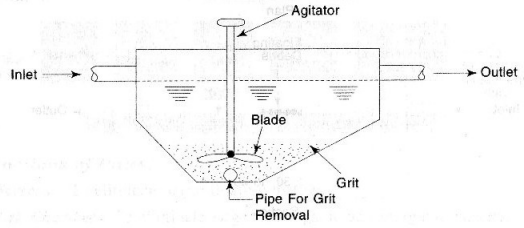


Fig. 8.3 *Grit chamber*

Working The sewage from the screen chamber is allowed to enter the grit chamber and flow at a low velocity of 20 cm to 30 cm per sec. Due to the low velocity, the grits, sands, etc. are settled down at the bottom of the grit chamber.

Cleaning At the time of cleaning, the deposited grits are agitated by agitator and the muddy water comes out through the removal pipe. The grits may also be cleared from top by manual labours with the help of buckets.

Disposal The grits are generally dumped in low-lying areas for the reclamation of land.

8.5 DETRITUS TANK

The function of detritus tank is to remove finer organic and inorganic particles. Practically, the detritus tank is similar to grit chamber. The only difference is that the grit chamber is meant for removing the larger particles and detritus tank is meant for removing finer particles.

Construction Figure 8.4 shows a detritus tank. It is a rectangular tank with vertical sides and tappered bottom and constructed with brick masonry. The depth of the tank varies from 2–3 m and the length varies from 20–40 m. The width depends on the volume of sewage to be treated. The velocity of flow varies from 15–20 cm per second and the detention period varies from 2 to 3 minutes.

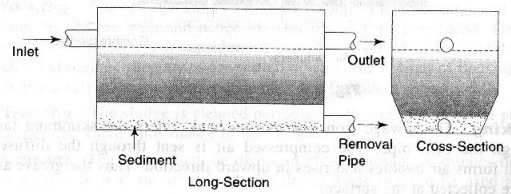


Fig. 8.4 *Detritus tank*

Working The sewage from the grit chamber is allowed to enter the detritus tank through inlet pipe. The sewage flows through the tank with low velocity. The finer suspended particles are settled down at the bottom of the tank.

Cleaning The deposited sediments are cleaned periodically through the removal pipe provided at the bottom of the tank. The sediments are agitated by scrappers, at the time of cleaning.

Disposal The sediments may be disposed of by dumping in low-lying areas for the reclamation of land.

8.6 SKIMMING TANK

Normally, the grease and oil are arrested by the grease and oil trap before the sewage enters the sewer line. But, these elements cannot be completely eliminated by the trap. The skimming tank is provided to remove the remaining portion of grease and oil from the sewage. Otherwise, these oily substances will cause disturbances in activated sludge process and tricking filter.

Construction It is a rectangular tank constructed with brick masonry. Air diffusers are provided at the bottom of the tank through which compressed air is sent to form bubbles in the sewage, as shown in Fig. 8.5. Bent pipes are provided at the inlet and outlet sides. C.I. covers are provided at the top for the removal of scum of grease and oil.

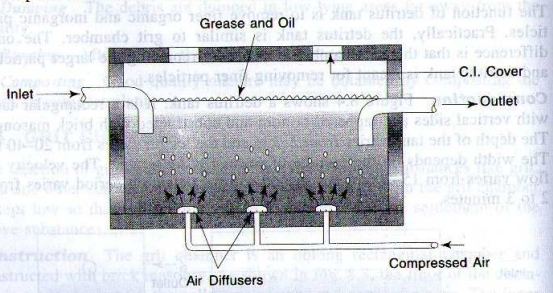


Fig. 8.5 *Skimming tank*

Working The sewage from the detritus tank enters the skimming tank through the bent pipe. The compressed air is sent through the diffusers which forms air bubbles and rises in upward direction. Thus the grease and oil are collected at the surface.

Cleaning By opening the C.I. covers the scum of the oily substances are removed periodically.

Disposal The oily substances are disposed of by burning.

8.7 PRIMARY SEDIMENTATION TANK

The primary sedimentation tank is also known as primary clarifier or primary settling tank. The purpose of this unit is to remove colloidal particles like silt and clay and some organic substance. Moreover, it reduces the load on the secondary treatment. Coagulants may be used, if necessary.

Construction Figure 8.6 shows the primary sedimentation tank. It is a rectangular tank constructed with brick masonry. Baffle walls are provided

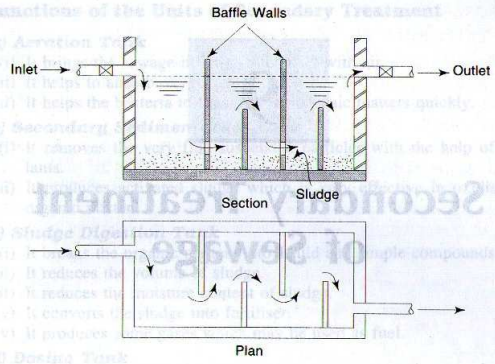


Fig. 8.6 *Primary sedimentation tank*

in zig zag way so as to lengthen the path of the flow of sewage. Inlet and outlet pipes are provided on opposite corners and these are provided with valves. A sludge removal pipe is provided at the bottom of the tank.

Working The sewage enters the tank through the inlet pipe and flows along the zig zag path and hence the velocity of flow is reduced. Thus the sewage is detained for a considerable period in the tank. The colloidal particles and organic substances are settled down at the bottom of the tank. The comparatively clear water passes out through the outlet pipe.

Cleaning The sludge is cleaned periodically through the removal pipe by opening the valve. (not shown in the fig.)

Disposal The sludge may be disposed of by dumping in ditches or low-lying areas or may be dried in sludge drying beds and can be used as manure.

REVIEW QUESTIONS

1. Why are screens provided in primary treatment? Describe the method of screening with sketch.
2. Describe a grit chamber with sketch.
3. Describe a detritus tank with sketch.
4. Describe a skimming tank with sketch.
5. State the functions of each unit provided in primary treatment.

9

Secondary Treatment of Sewage

9.1 INTRODUCTION

In the primary treatment, the larger solids in sewage are removed. But the effluent still contains organic matters, bacteria, colloidal matters, etc. Such effluent cannot be discharged into the natural water coarse. So secondary treatments are given to the effluent of primary treatment to make it safe in all respects and suitable for discharging into the river. The most important units in this stage are: (a) Activated sludge process and (b) Filtration of sewage.

There are some other units which are allied with these main treatments. The sequence of the secondary treatment is shown in the next section.

9.2 FLOW DIAGRAM OF SECONDARY TREATMENT

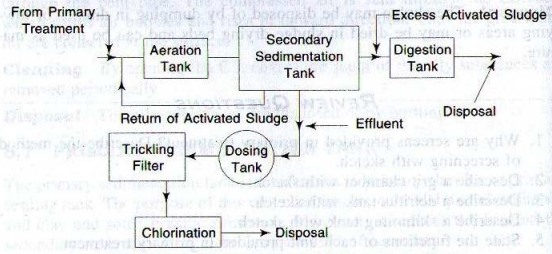


Fig. 9.1 *Flow diagram of seconday treatment*

Functions of the Units of Secondary Treatment

(a) Aeration Tank

(i) It brings the sewage in intimate contact with air.
(ii) It helps to absorb oxygen from air.
(iii) It helps the bacteria to break up the organic matters quickly.

(b) Secondary Sedimentation Tank

(i) It removes the very fine suspended particles with the help of coagulants.
(ii) It produces activated sludge which is very effective in oxidising the organic matters.

(c) Sludge Digestion Tank

(i) It breaks the organic matters into liquid and simple compounds.
(ii) It reduces the volume of sludge.
(iii) It reduces the moisture content of sludge.
(iv) It converts the sludge into fertiliser.
(v) It produces some gases which may be used as fuel.

(d) Dosing Tank

(i) It provides uniform spreading arrangement of sewage over the trickling filter.
(ii) It provides intermittent dosing of sewage by automatic siphonic device.

(e) Trickling Filter

(i) It removes the total solids of sewage.
(ii) It reduces the B.O.D.
(iii) It gives clear effluent.

(f) Chlorination of Sewage

(i) It disinfects the sewage by chlorine.
(ii) It prevents the corrosion of sewers.
(iii) It prevents the growth of algae and other plants life in sewer.

9.3 AERATION TANK

The process of absorbing oxygen from air is known as aeration. The aeration of sewage is the most vital operation in activated sludge process. Due to aeration, the sludge containing bacteria becomes more powerful in decomposing the sewage quickly. Hence, the aeration is the first step of secondary treatment.

The aeration is achieved by providing air diffusers in aeration tank. The air diffusers may be of the following three types:

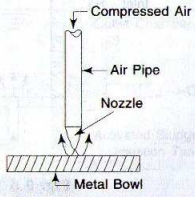


Fig. 9.2 *Jet diffuser*

(a) Jet Diffuser In this method, the compressed air is thrown with high velocity over a metal bowl through the nozzle as shown in Fig 9.2. The jet of air

strikes the surface of bowl and reflects upwards in the form of bubbles. Thus the sewage is agitated and it absorbs oxygen from the air.

(b) Plate Diffuser In this method, the compressed air is blown through a perforated diffuser plate. The air rushes out through the holes of the diffuser plate and rises upwards in the form of bubbles, as shown in Fig 9.3. Thus, the sewage absorbs oxygen from air.

(c) Tube Diffuser Figure 9.4 shows a tube diffuser. It is about 60 cm long and internal diameter is about 7.5 cm. The end of the tube is sealed with a cap. The tube is perforated with oblong holes around its surface. It is fixed in the air pipe and submerged in water up to the required depth. The compressed air is sent through the tube. The air comes out through the holes with great force and agitate the water or sewage.

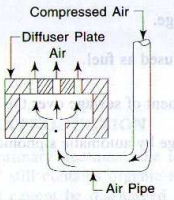


Fig. 9.3 *Plate diffuser*

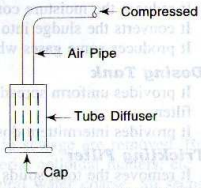


Fig. 9.4 *Tube diffuser*

Types of Aeration Tank

The aeration tanks may be of the following types:

(a) Ridge and furrow type tank
(b) Spiral flow type tank

(a) Ridge and Furrow Type Tank Figure 9.5 shows the ridge and furrow type tank. It is a rectangular tank with ridges and furrows at the

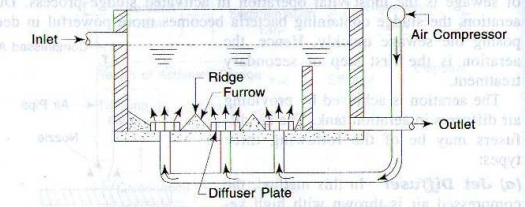


Fig. 9.5 *Ridge and furrow type tank*

bottom. The plate diffusers are provided at the furrows. The sewage is allowed to enter the tank through the inlet pipe at the top and after aeration it is discharged through the outlet pipe at the bottom. The size of the tank depends on the volume of sewage to be treated. In general, the size is 10 m long, 5 m wide and 3 m deep. An air compressor is provided for supplying air to the diffuser plates through the air distributing pipe. The compressed air comes out of the holes of the diffuser and rises up in the form of bubbles.

(b) Spiral Flow Type Tank It is a rectangular tank constructed with brick masonry. A series of tube diffusers are submerged in sewage by air pipes which are connected to the air distribution pipe. A curved baffle wall is provided in front of the diffusers, as shown in Fig. 9.6. When the compressed air is sent through the diffusers, the air bubbles pass over the curved surface of the baffle and gain a spiral motion within the tank. The size of the tank depends on the volume of sewage to be treated.

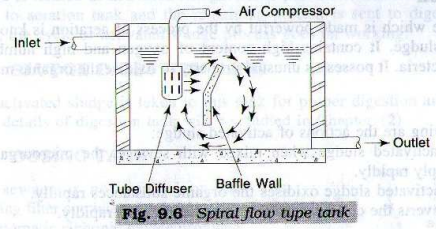


Fig. 9.6 *Spiral flow type tank*

9.4 SECONDARY SEDIMENTATION TANK

The secondary sedimentation tank is also known as secondary clarifier or secondary settling tank. The following are salient features of the tank:

Construction It is a rectangular tank constructed with brick masonry. A baffle wall is provided in the tank to divide it into two zones. The floor of each zone is made sloping towards the side as shown in Fig. 9.7. The inlet and outlet arrangements are made through the chambers and the sludge re-

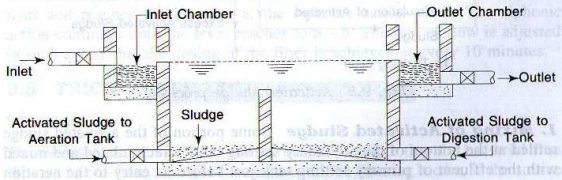


Fig. 9.7 *Secondary sedimentation tank*

moval pipes are provided on both sides. Generally, the length of the tank is three times the width. The detention period is generally 1 hour.

Working The aerated sewage is allowed to enter the tank through the inlet chamber and it is detained for one hour in the tank. The sludge is deposited at the bottom of the tank. This sludge becomes activated due to aeration. The effluent is discharged through the outlet chamber and taken to the trickling filter.

Recirculation of Sludge Some portion of the activated sludge is recirculated to the aeration tank by pumping.

Disposal of Excess Sludge The excess sludge is taken to the sludge digestion tank for digestion and final disposal.

9.5 ACTIVATED SLUDGE PROCESS

Definition

The sludge which is made powerful by the process of aeration is known as activated sludge. It contains high content of oxygen and high number of aerobic bacteria. It possesses unusual property to oxidise the organic matters.

Action

The following are the actions of activated sludge:

(i) The activated sludge when mixed with sewage, the microorganisms multiply rapidly.
(ii) The activated sludge oxidises the organic substances rapidly.
(iii) It converts the colloidal matters to settleable size rapidly.

Operational Features

Figure 9.8 shows the various stages of activated sludge process. The activated sludge process consists of the following operations:

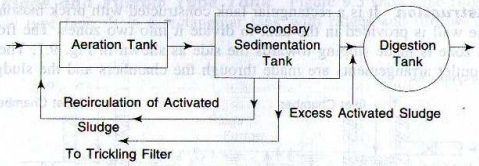


Fig. 9.8 *Activated sludge process*

1. Mixing of Activated Sludge Some portion of the activated sludge settled at the bottom of the secondary settling tank is recirculated and mixed with the effluent of primary settling tank just before its entry to the aeration tank.

2. Aeration Aeration tank is the first unit of the activated sludge process. Here, the effluent of primary settling tank and air are brought in intimate contact by agitating with some mechanical devices. The devices are as follows:

(a) Air diffuser system
(b) Mechanical aeration system
(c) Combination of air diffuser and mechanical aeration.

Generally, air diffuser system is adopted for aeration. This system may be achieved by (i) Jet diffuser, (ii) Plate diffuser or (iii) Tube diffuser. These systems are described in Section 9.3.

Sludge Settlement The secondary sedimentation tank is the second unit. After agitation in aeration tank, the effluent is taken to the secondary settling tank and detained for a specified period (generally, 1 hour). During this detention period, the sludge is settled at the bottom of the tank. This sludge is termed as activated sludge. Some portion of this sludge is recirculated to aeration tank and the remaining portion is sent to digestion tank. Thus, the cycle of activated sludge process goes on working.

9.6 SLUDGE DIGESTION TANK

The activated sludge is taken to this tank for proper digestion and disposal. (The details of digestion tank will be studied in Chapter 12)

9.7 DOSING TANK

The sewage is not applied on the trickling filter continuously. It is applied by automatic siphonic device provided with the dosing tank. As shown in Fig. 9.9, it consists of a U-pipe with its vertical end inserted into the tank. A hood is provided over the free end of the pipe. The other end of U-pipe is connected to the inlet pipe of trickling filter. When the level of sewage remains on the line b – b, there will be no siphonic action. When the level rises and reaches the line a – a, the siphonic action starts. The siphonic action continues until the level reaches to b – b. The rate of flow is adjusted in such a way that the dosing of the filter is achieved at every 10 minutes.

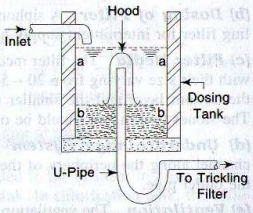


Fig. 9.9 *Dosing tank*

9.8 TRICKLING FILTER

Theory

The theory of trickling filter is based on the principle that the bacterial film (known as bio-film) which is formed around the filtering media, is the source

of formation of the bacterial colonies. These bacteria decompose the organic matters for their survival. So, the trickling filter serves the purpose of breaking the complex organic matter by fertilising the bacteria.

Elements of Trickling Filter

The following are the elements of trickling filter:

(a) Construction of Filter Figure 9.10 shows a trickling filter. Generally, the trickling filter is circular in shape. It consists of four numbers of rotary distributing arms which have perforations at the bottom. The arms are fitted with a central support which is rotated by a suitable device. The floor of the filter is made of concrete and its slope is made towards the periphery.

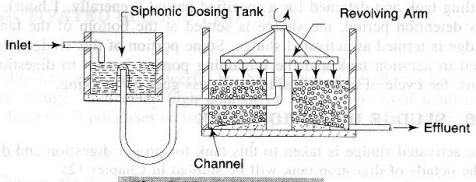


Fig. 9.10 *Trickling filter*

(b) Dosing of Filter A siphonic dosing tank is provided with the trickling filter for intermittent supply of effluent over the filtering media.

(c) Filter Media The filter media consists of broken stones, clinkers, etc. with their size varying from 20 – 50 mm. The larger size stones are placed at the bottom layer and the smaller size stones are arranged towards the top. The stones or clinkers should be of good quality.

(d) Underdrainage System The underdrainage system consists of a channel along the periphery of the filter. The channel again is connected to the outlet pipe.

(e) Ventilation The ventilation of filter is necessary for the smooth working of the filter. The ventilation is achieved by providing vent pipes at the periphery. (not shown in fig.)

(f) Working The effluent is spread over the filtering media of broken stones by rotary arms. The effluent trickles down the media and gets collected in the channel. The channel carries the effluent to the outlet pipe through which the effluent is taken for chlorination.

(g) Cleaning After working for long period, the upper surface of the media may be clogged by sediments. The rate of filtration may be decreased or stopped due to this. At that time, the upper layer of stones are scrapped off and fresh layer of stones of same size are replaced properly.

9.9 CHLORINATION OF SEWAGE

Necessity

The chlorination of sewage is done for the following reasons:

(a) It prevents the growth of algae and other plant life in sewers.
(b) It prevents the corrosion of sewers.
(c) It protects the aquatic life.
(d) It eliminates the odour from effluent.

Chlorination Tank

The chlorination tank is a rectangular chamber constructed of brick masonry. It consists of a vertical shaft and horizontal shaft. The horizontal shaft consists of several paddles which are rotated by a driving unit. The dosing of chlorine is done in a dosing chamber through a funnel, as shown in Fig. 9.11. Generally, the dose varies from 10 to 20 ppm and the contact period is 15 minutes.

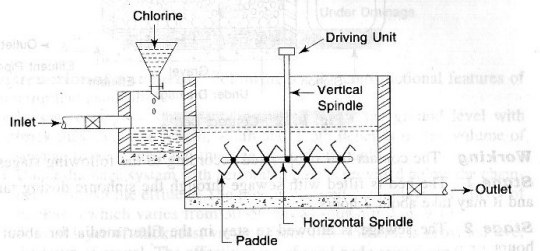


Fig. 9.11 *Chlorination tank*

The requisite amount of chlorine is added to the effluent in dosing chamber and then it flows to the chlorination tank. In chlorination tank, the effluent is thoroughly mixed with chlorine by rotating the paddles. After 15 minutes of detention period, the effluent is allowed to flow to the natural water course.

9.10 CONTACT BED

Like trickling filter the contact bed is a method of filtration of sewage. But, the rate of filtration is low in comparison with trickling filter.

Theory In contact bed, the sewage is brought in contact with the filtering media for some specified period. During this period, a biological film is formed around the particles of the filter media and the bacterial colonies are formed in the film. These bacteria are responsible for the oxidation of organic matters. Again, when the bed is kept empty for some period, the filter gets

oxygen from atmosphere and oxides the organic matters if they remain unoxidised.

Construction It is a rectangular tank which is divided into several beds (i.e. sectors). The depth of bed varies from 1m to 2m. Each bed is filled up with filtering media of gravel, ballast or broken stones, as shown in Fig. 9.12. The effective size of ballast varies from 15 mm to 50 mm. A siphonic dosing tank is provided for the supply of sewage to all the beds simultaneously. Generally, the rate of filtration is 500 lits per m^3 of filter media.

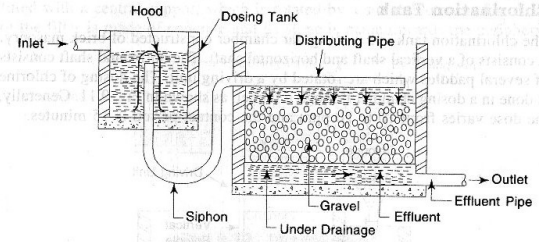


Fig. 9.12 *Contact bed*

Working The contact bed is operated according to the following stages:

Stage 1 The bed is filled with sewage through the siphonic dosing tank and it may take about 2 hours.

Stage 2 The sewage is allowed to stay in the filter media for about 2 hours.

Stage 3 The effluent is allowed to flow through the effluent pipe for the disposal to natural water course. This may take about 2 hours.

Stage 4 The bed is allowed to stay empty for about 4 hours. Thus, the cycle of operation continues during the working period.

Disadvantages

(a) The effluent is turbid.
(b) The removal of bacteria is low.
(c) Rate of filtration is low.
(d) It requires long time.
(e) It is suitable for small establishment.

9.11 INTERMITTENT SAND FILTER

Theory In intermittent sand filter the sewage is purified by the phenomenon of mechanical straining through the sand bed and by bacterial colonies

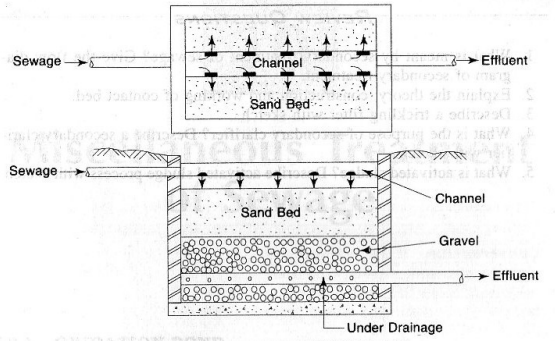


Fig. 9.13 *Intermittent sand filter*

Constructional Features Following are the constructional features of an intermittent sand filter:

(a) It is a rectangular chamber constructed below the ground level with brick masonry. The length, width and depth depends on the volume of sewage to be treated and the area of land available.
(b) Under drainage system with perforated pipe is provided below the chamber to collect the effluent. The pipe is covered with a layer of gravel of thickness which varies from 30–50 cm as shown in Fig. 9.13.
(c) A sand layer of thickness, varying from 100–150 cm, is provided over the layer of gravel. The effective size of sand bed varies from 0.20–0.50 mm and uniformity coefficient varies from 2–5.

Working

(a) The sewage is allowed to flow through the distribution channel and spread over the sand bed. When the depth of sewage is about 10 – 20 cm, the supply is cut-off and left for several days.
(b) The process of filtration goes on and the effluent passes through the underdrainage system. The sludge is retained over the sand bed.
(c) The top layer of sand should be raked properly before starting the next operation.
(d) When the process of filtration is highly disturbed due to the formation of thick scale over the sand bed, the top layer of sand should be removed and a fresh layer of sand should be spread evenly.

Efficiency

(a) The effluent is very clear.
(b) Removes suspended solids to about 90%.
(c) Free from odour.

REVIEW QUESTIONS

1. What is meant by secondary treatment of sewage? Give the flow diagram of secondary treatment.
2. Explain the theory, construction and working of contact bed.
3. Describe a trickling filter with sketch.
4. What is the purpose of secondary clarifier? Describe a secondary clarifier with sketch.
5. What is activated sludge? Describe activated sludge process with sketch.

10

Miscellaneous Treatment of Sewage

10.1 OXIDATION POND

Theory The oxidation pond is an excavation of rectangular ditch of shallow depth. The sewage is stored in this pond for a considerable time. During this period, the sewage is decomposed by the action of aerobic bacteria, algae and sunshine. That means, it is a natural method of sewage treatment. The aerobic bacteria absorbs oxygen from the atmosphere for their survival and break up the organic matters in sewage to simple stable compounds.

Construction and Operation The oxidation pond is constructed by excavating a rectangular ditch of shallow depth. The length varies from 50–100 m, the width from 30–50 m and the depth varies from 0.9–1.5 m. The pond is divided into several compartments by small levees in a zig-zag manner, as shown in Fig. 10.1. The sewage is allowed to enter the pond through the inlet channel at one corner. The sewage flows in a zig-zag manner until the whole pond is filled up. The detention period varies from 7–14 days. The decomposition of sewage is achieved by the aerobic bacteria. After complete decomposition a black humus (i.e. sludge) is obtained which may be used as manure. (Fig. 10.1)

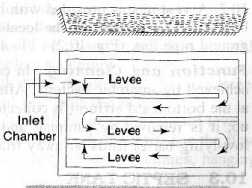


Fig. 10.1 *Oxidation pond*

Advantages

(a) It is a natural method of decomposition, so it is cheap.
(b) Its operation and maintenance is simple.
(c) It is highly efficient in removing B.O.D.